



**UNITED STATES AIR FORCE  
RESEARCH LABORATORY**

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**E-3 In-flight Acoustic Exposure Studies  
and Mitigation Via Active Noise  
Reduction Headset**

Frank Mobley  
John Allan Hall  
Donald Yeager

December 2002

Final Report for the Period 1 October to 31 October 2002

*Approved for public release; distribution is unlimited.*

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AFRL-HE-WP-TR-2003-0093

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Instruction 40-402.

This technical report has been reviewed and is approved for publication.

## **FOR THE COMMANDER**

//Signed//

MARIS M. VIKMANIS  
Chief, Crew System Interface Division  
Air Force Research Laboratory

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## SUMMARY

*The purpose of this initiative was to survey representative acoustic exposures encountered by aircrews aboard the E-3 Sentry (AWACS) and evaluate the ability of active noise reduction headset technology to mitigate aircrew exposure. Aviation noise associated with engines, aerodynamics, avionics, communications, power units, and other subsystems aboard the aircraft has long been a source of occupational hearing loss within the military flying community. Hearing loss can negatively impact critical phases of any flying mission, and this is particularly true of the E-3 since it is a primary airborne command and control platform for the U.S. military and NATO.*

*E-3 sorties can be long duration, averaging 8 to 14 hours or more. Continuous exposure at the ear to acoustic noise above 85 dBA for 8 hours poses a risk to human hearing that can be calculated in terms of Total Daily Exposure (TDE), which should not exceed one (1.0). This metric can also be presented as noise "dose" not to exceed 100% (see Air Force Occupational Safety and Health Standard 48-19 on Hazardous Noise, and the federal OSHA Noise Standard in the Federal Register, Volume 48 No. 46).*

*This project surveyed representative samples of in-flight noise experienced by the aircrew throughout the E-3 at cruise by use of sub-miniature microphones worn on the human ear, connected to a digital recording device. The microphones were worn under the most common USAF aviation headset (David Clark H1076) and under an active noise reduction (ANR) headset (David Clark H1076-XL). Data were analyzed at the Air Force Research Laboratory, Wright-Patterson AFB, Ohio.*

*Results indicated that the active noise reduction headset would significantly reduce the total daily acoustic exposure at the ear of the individual wearing the ANR headset in a variety of locations aboard the E-3 at cruise.*

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## PREFACE

This project was conducted by the Air Force Research Laboratory's Human Effectiveness Directorate, (Crew System Interface Division) (AFRL/HEC). The project coordinator was LtCol Brian Donnelly. The measurements, analysis, and report were accomplished by Mr. Frank Mobley, Mr. John Allan Hall, and TSgt Don Yeager. Mr. Ken Johnson provided equipment and technical support for AFRL. Mr. Sam Seagle provided technical support from the Electronic Systems Center (ESC) and Mrs. Shirley Godsil provided technical support at the 552 Air Combat Wing. This research is designated within the 6.2 Program "Bioacoustics and Hearing Protection," under Work Unit Number 71841607.

The field research was conducted on 7 October 2002 at Tinker Air Force Base, OK. The subsequent analysis occurred at Wright-Patterson Air Force Base, OH.

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## **INTRODUCTION**

### **BACKGROUND**

The purpose of this acoustic measurement is to lay out the requirements, needed to evaluate the noise characteristics of the E-3 aircraft, for occupational and environmental noise documentation required by the United States Air Force (USAF). In-flight noise data were acquired at Tinker Air Force Base. These data were used to update the database on aircraft noise and effects on flight crew and maintainers of the E-3 aircraft. Air Force Research Laboratory Human Effectiveness Directorate (AFRL/HECB) standard procedures for in-flight data acquisition and analysis were followed to insure that the resultant one-third octave band data are accurate to at least  $\pm 2$  dB over the frequency range of 50 to 5000 Hz and  $\pm 3$  dB over the frequency range of 6,300 to 10,000 Hz. The A-weighting (dBA) is a standard filter (ANSI Std. S1.4-1971) applied to one-third octave band sound pressure levels (dB-SPL) that most closely correlate to damage risk to human hearing according to international standards.

Continuous exposure at the ear to acoustic noise above 85 dB (A-weighting) for 8 hours poses a risk to human hearing that can be calculated in terms of Total Daily Exposure (TDE) which should not exceed one (1.0). This metric can also be presented as noise "dose" not to exceed 100% (see Air Force Occupational Safety and Health Standard 48-19 on Hazardous Noise, and the federal OSHA Noise Standard in the Federal Register, Volume 48 No. 46). AFRL research indicates the 3dB exchange per doubling of time rule holds for durations over 8 hours. Therefore 82.56 dB (A-weighting) is the level not to exceed for a 14-hour mission sortie.

### **PURPOSE**

The purpose of this effort was to measure noise generated by the E-3 aircraft during selected flight operating conditions. The data will be utilized to address noise exposure risk to crewmember hearing. The data will also determine the relative benefit of Active Noise Reduction (ANR) headset technology to mitigate crew acoustic exposure. Two types of headsets were worn for this test. One was representative of the current hearing protection devices, the David Clark H1076; the other was an ANR headset, the David Clark H1076-XL.

## METHOD

### DESCRIPTION OF TEST AIRCRAFT

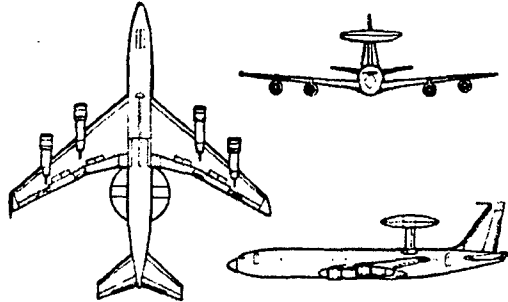


Figure 1. Line Drawing of the E-3.

The E-3 Sentry is an airborne warning and control system (AWACS) aircraft that provides all-weather surveillance, command, control and communications needed by commanders of U.S., NATO and other allied air defense forces. As proven in Operation Allied Force, it is the premier air battle command and control aircraft in the world today. This flight was a typical eight-hour training mission. The profile took the aircraft East from Tinker AFB out to an orbit in the Atlantic just off the coast of Maryland. The E-3 crews practiced air control of "Red" and "Blue" sorties from Langley AFB who were sparing against each other. Following two "fights" the E-3 returned to Tinker AFB, OK.

**Primary Function:** Airborne surveillance, command, control and communications

**Builder:** Boeing Aerospace Co.

**Power Plant:** Four Pratt and Whitney TF33-PW-100A turbofan engines

**Thrust:** 21,000 pounds (9,450 kilograms) each engine

**Length:** 145 feet, 6 inches (44 meters)

**Wingspan:** 130 feet, 10 inches (39.7 meters)

**Height:** 41 feet, 4 inches (12.5 meters)

**Rotodome:** 30 feet in diameter (9.1 meters), 6 feet thick (1.8 meters), mounted 11 feet (3.33 meters) above fuselage

**Speed:** Optimum cruise 360 mph (Mach 0.48)

**Ceiling:** Above 29,000 feet (8,788 meters)

**Maximum Takeoff Weight:** 347,000 pounds (156,150 kilograms)

**Endurance:** More than 8 hours (non-refueled)

**Unit Cost:** \$123.4 million (fiscal 98 constant dollars)

**Crew:** Flight crew of four plus mission crew of 13-19 specialists  
(mission crew size varies according to mission)

## TEST CONDITIONS

All E-3 Crew Position Numbers are designated as in the Aircrew Aids, pp. A-01, dated 1 Dec 96.

**Table 1. Test Conditions for E-3 In-flight Measurements Using Current Hearing Protection Device.**

Condition	Power Setting
1	Taxi, Seat 5
2	Takeoff, Seat 5
3	Climb, Seat 5
4	Cruise, Seat 5
5	Cruise, Seat 7
6	Cruise, Seat 11
7	Cruise, Seat 14
8	Cruise, Seat 25
9	Cruise, Below Deck
10	Cruise, Bed Bunks

**Table 2. Test Conditions for E-3 In-flight Measurements Using Proposed Hearing Protection Device.**

Condition	Power Setting
11	Climb, Back Bay
12	Cruise, Back Bay
13	Cruise, Seat 25
14	Cruise, Lower Deck
15	Cruise, Seat 11
16	Cruise, Seat 7
17	Cruise, Seat 24

## EQUIPMENT

Cockpit noise data collection equipment was developed by AFRL (the Crew System Interface Division's Aural Displays & Bioacoustics Branch) to evaluate aircraft noise reaching the ear canal opening of crewmembers. The instrumentation consists of a small lightweight digital recorder, a specialized miniature microphone worn at the entrance to the ear, and another microphone to be secured on the outside of the wearer's helmet or headset. The system in no way interferes with avionics, flight controls, life support equipment, or communications. The equipment has been thoroughly tested in accordance with Mil Std. 461 for electromagnetic interference (radiated emissions), all connections have been "break-away" tested for emergency egress conditions, and all instrumentation has been evaluated in an explosive atmosphere. The recorder is worn inside the pocket of the crewmember's flight suit. The recorder system (to include microphones) is calibrated to a 94 dB-SPL calibration signal at 1 kHz.

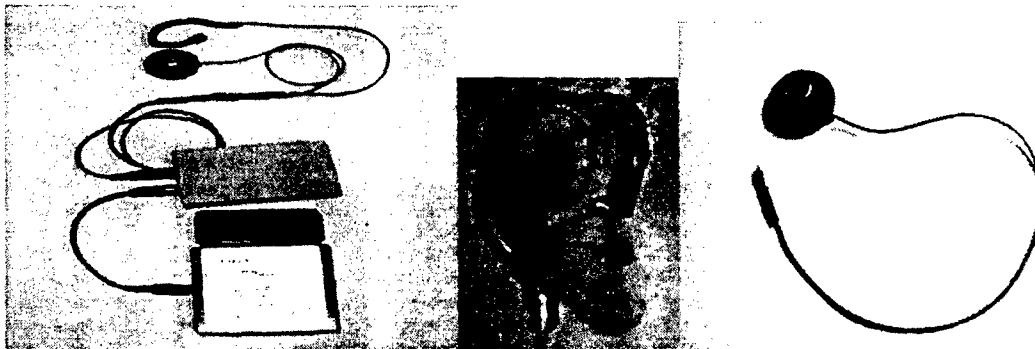


Figure 2. In-flight Recording System.

## ANALYSIS

The recordings were analyzed using a Hewlett Packard 35665A 2-channel dynamic signal analyzer. The internal and external microphone data are analyzed at the same time to provide a correlation between the ambient and ear microphone. The data are output into an Excel file with charts generated to display the dBA as a function of time and the spectra for the maximum and minimum A-weighted value. The A-weighted time histories are presented in Appendix A. Mission representative spectral samples are presented in the next section. More spectral samples than necessary were collected for the purpose of gathering sufficient samples to validate the data collection.

$$\text{Max Time} = 8 \text{ hr} \times 2^{-(L_A - 85 \text{ dBA}) / 3 \text{ dBA}}$$

Equation 1. This Equation is used to determine the maximum time a human may stay in a noise environment.

Exposures were calculated based on an average level that was found through an energy average of the selected time histories. This level was then inserted into Equation 1 as the  $L_A$  to determine the maximum time that an aircrew member can remain in this environment using a specific headset. This equation is based on Air Force Occupational Safety and Health Standard 48-19.

The following graphs are presented in accordance with the following convention:

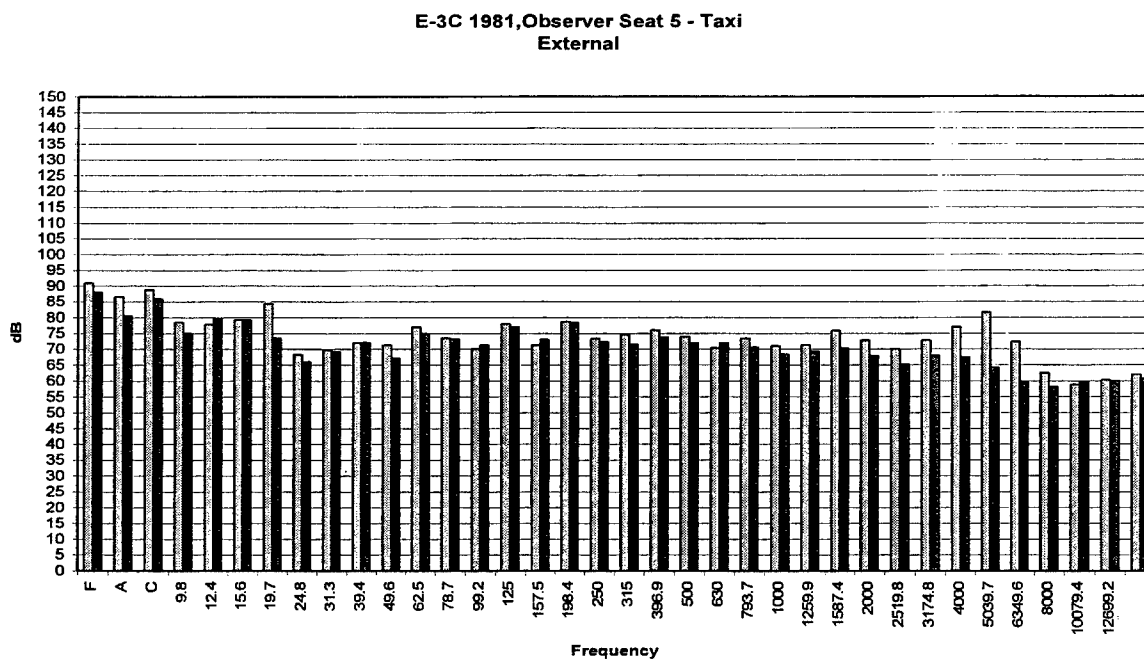
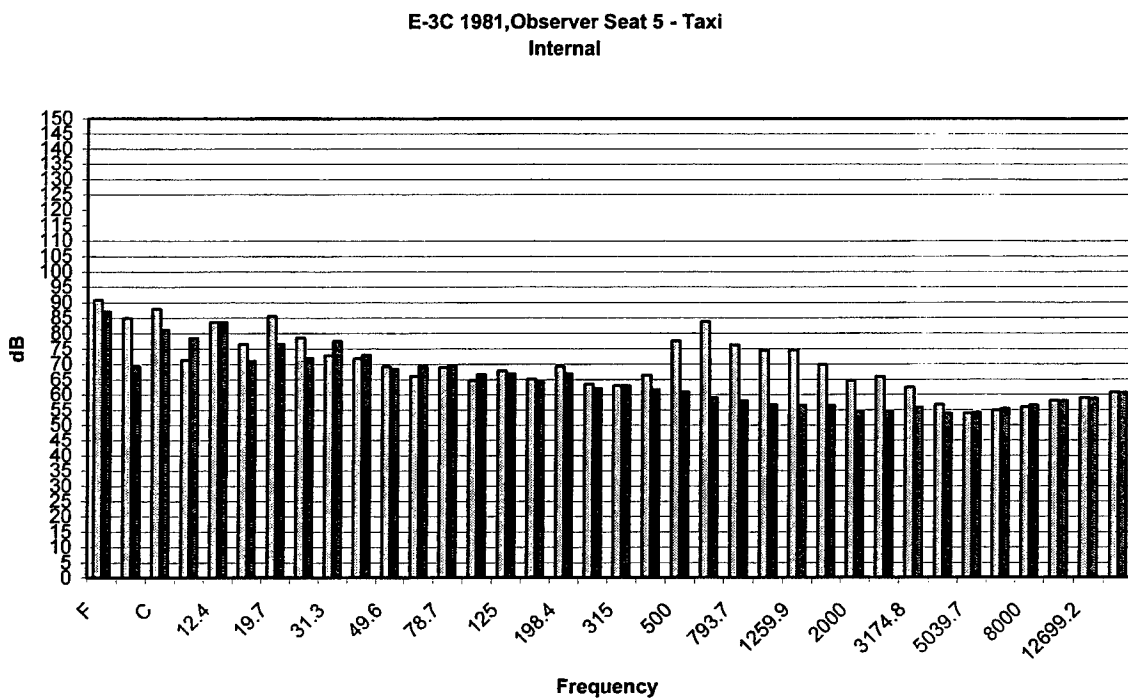
### Spectral graph explanation:

- The overall unweighted ("flat") Sound Pressure Level (dB-SPL) is denoted by "F"
- The overall A-weighted level (dBA) is denoted by "A"
- The overall C-weighted level (dB-C) is denoted by "C"
- The 1/3<sup>rd</sup> octave band center frequencies following F, A, C
- The lighter shaded bars are the 1/3<sup>rd</sup> octave band levels of the sample corresponding to **maximum** A-weighting
- The darker shaded bars are the 1/3<sup>rd</sup> octave band levels of the sample corresponding to the **minimum** A-weighting
- The graphs labeled "**Internal**" depict data collected via the **ear mounted mic under the headset**
- The graphs labeled "**External**" depict data collected via the **mic mounted on headset externally**



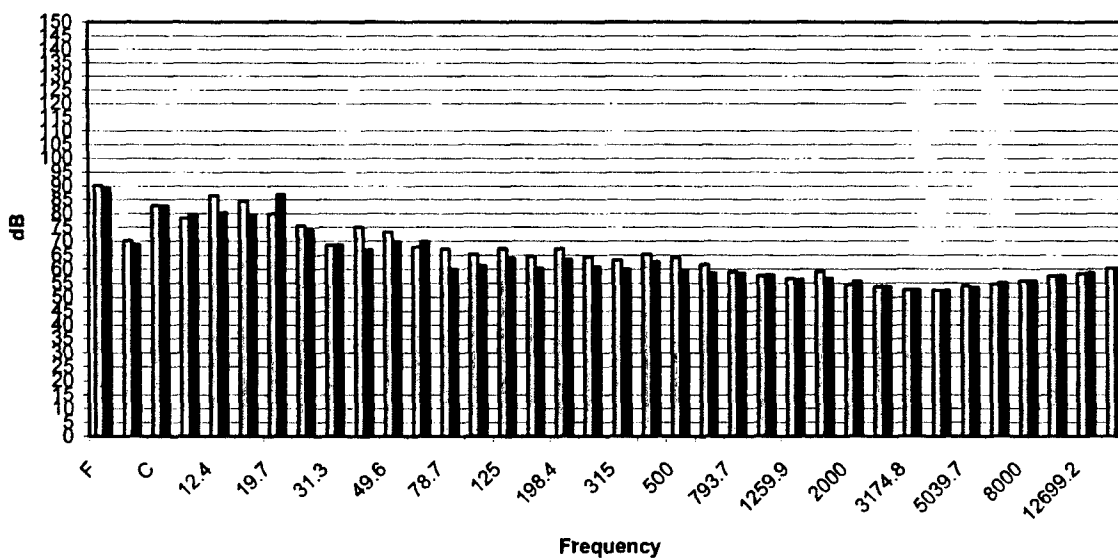
## RESULTS

### *In-Flight Spectral Data For David Clark 1076 Headset (Conventional Headset)*



**Figure 3. Internal and External Spectral Data for Condition 2 (Conventional Passive Headset).**

E-3C 1981, Observer Seat 5 - Takeoff  
Internal



E-3C 1981, Observer Seat 5 - Takeoff  
External

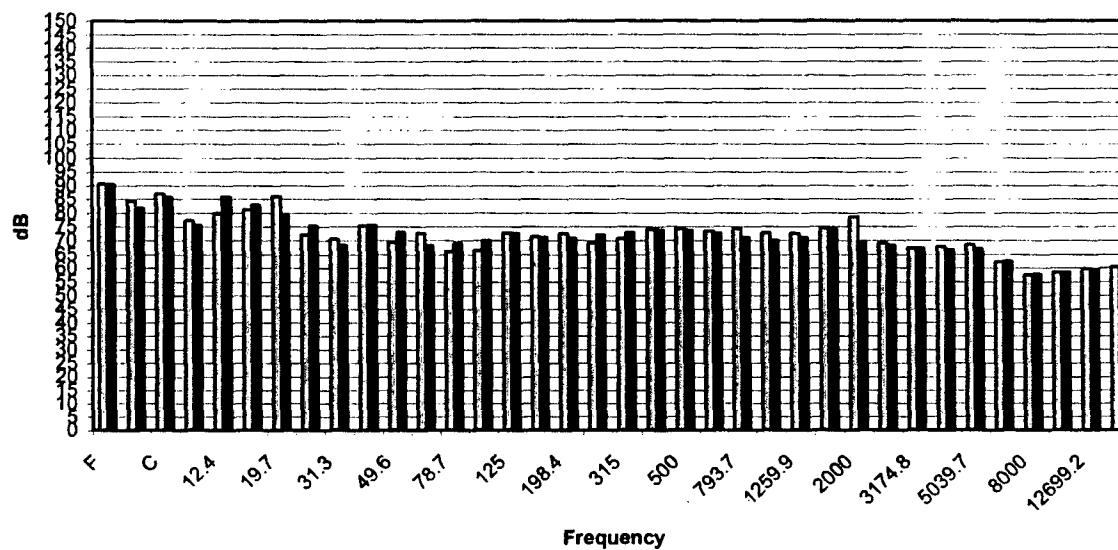
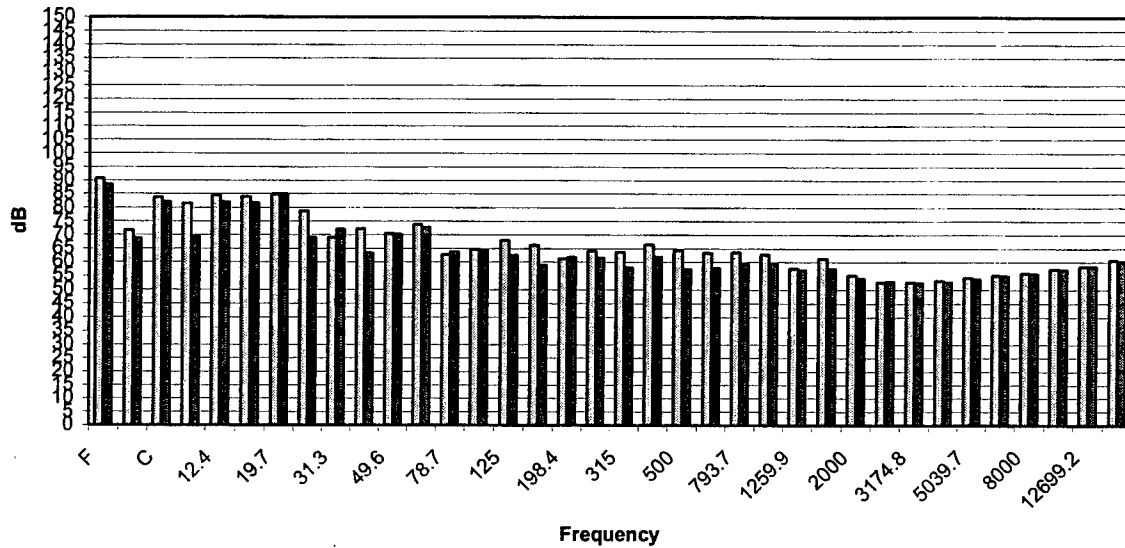


Figure 4. Internal and External Spectral Data for Condition 2 (Conventional Passive Headset).

E-3C 1981, Observer Seat 5 - Climb  
Internal



E-3C 1981, Observer Seat 5 - Climb  
External

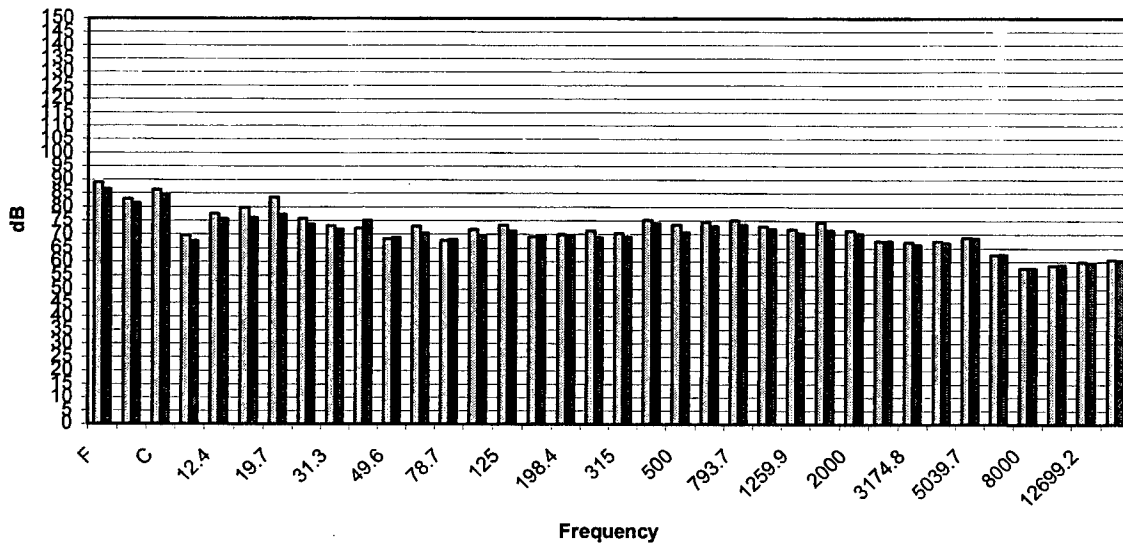
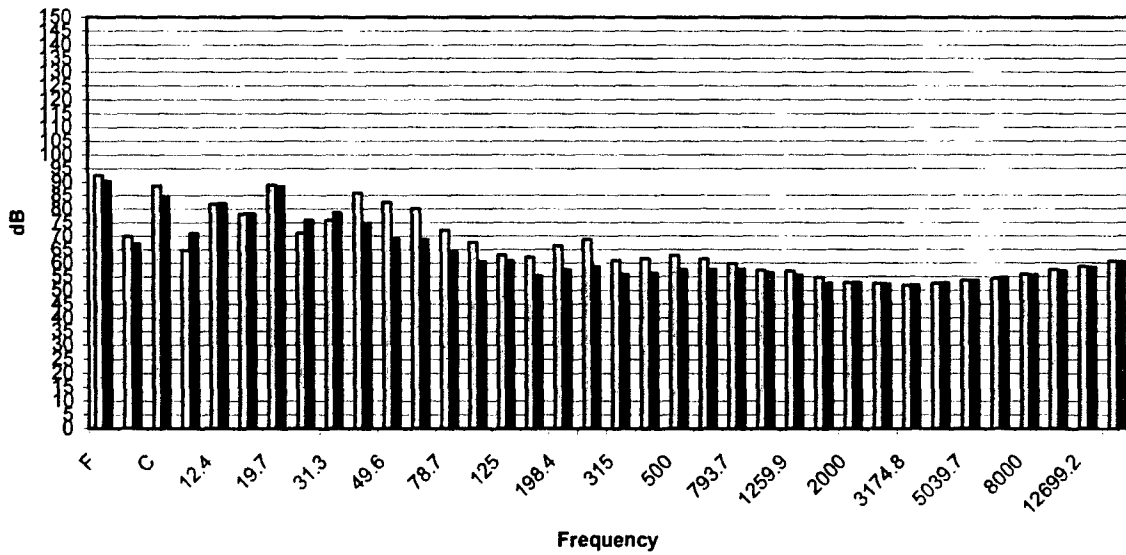


Figure 5. Internal and External Spectral Data for Condition 3 (Conventional Passive Headset).

E-3C 1981, Observer Seat 5 - Cruise  
Internal



E-3C 1981, Observer Seat 5 - Cruise  
External

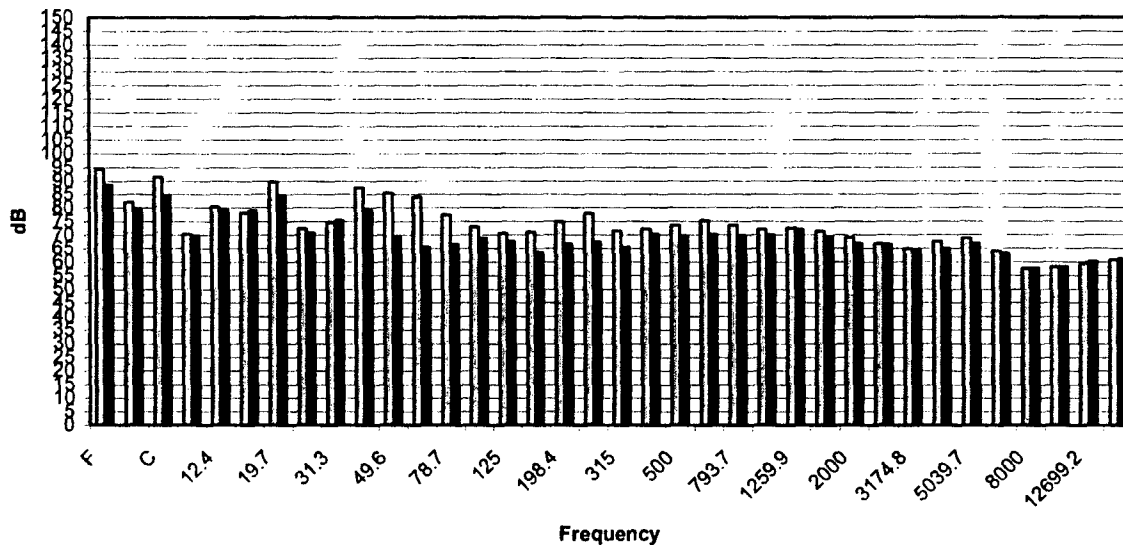
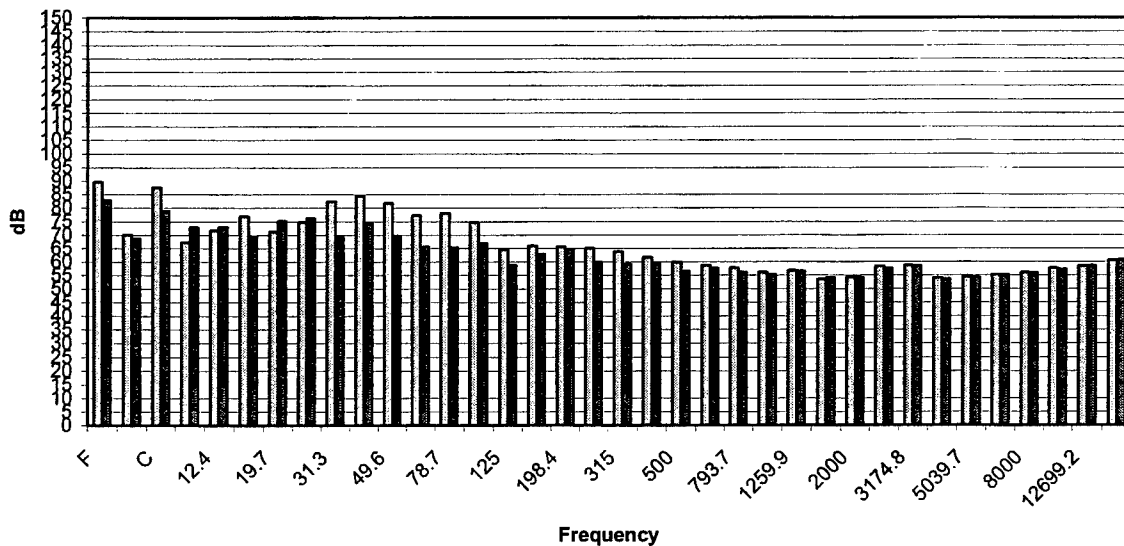


Figure 6. Internal and External Spectral Data for Condition 4 (Conventional Passive Headset).

E-3C 1981, Seat 25 - Cruise  
Internal



E-3C 1981, Seat 25 - Cruise  
External

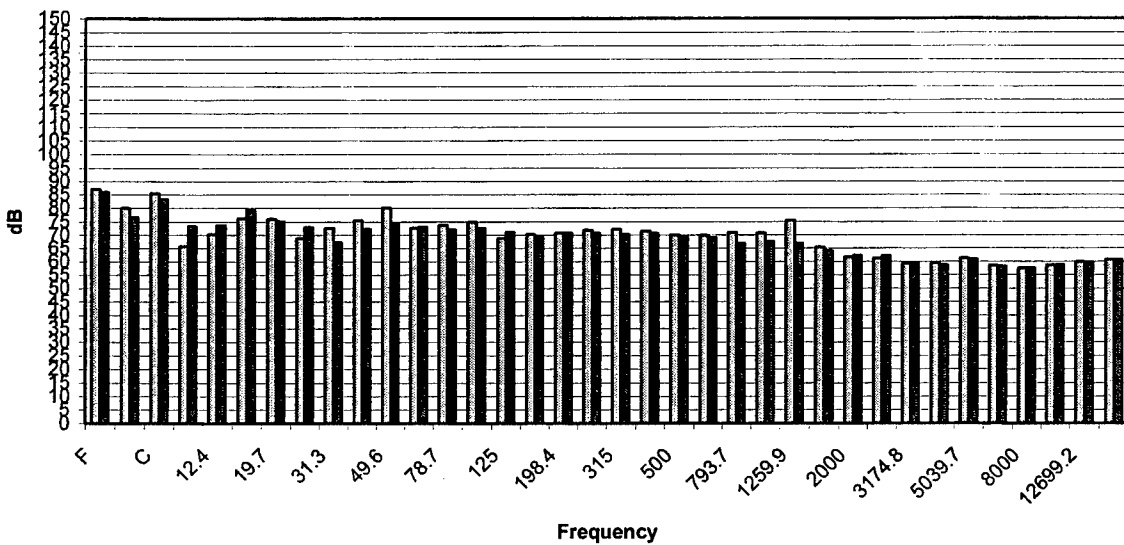
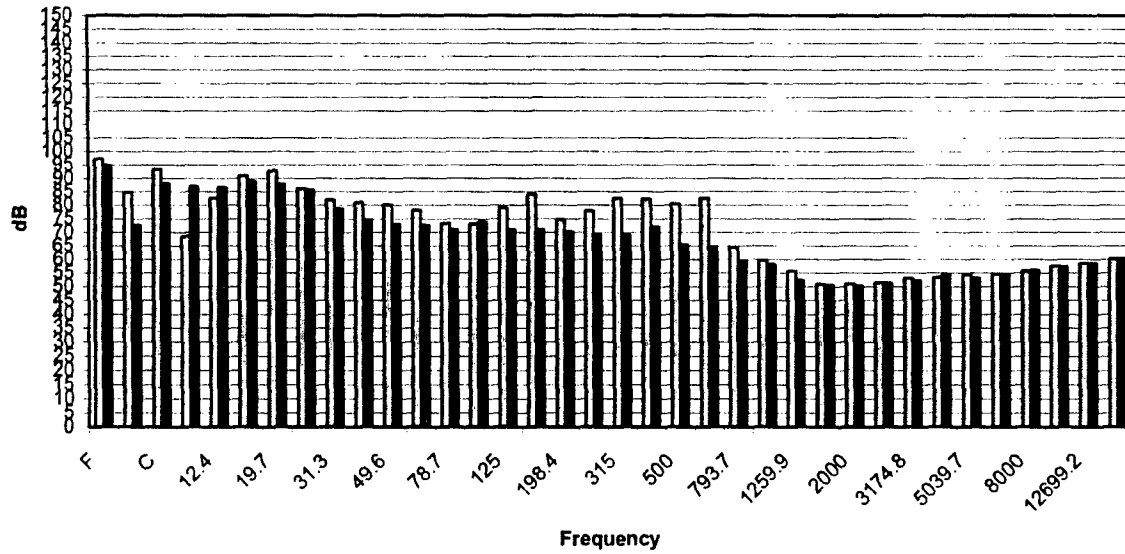


Figure 7. Internal and External Spectral Data for Condition 5 (Conventional Passive Headset)

E-3C 1981, Seat 11 - Cruise  
Internal



E-3C 1981, Seat 11 - Cruise  
External

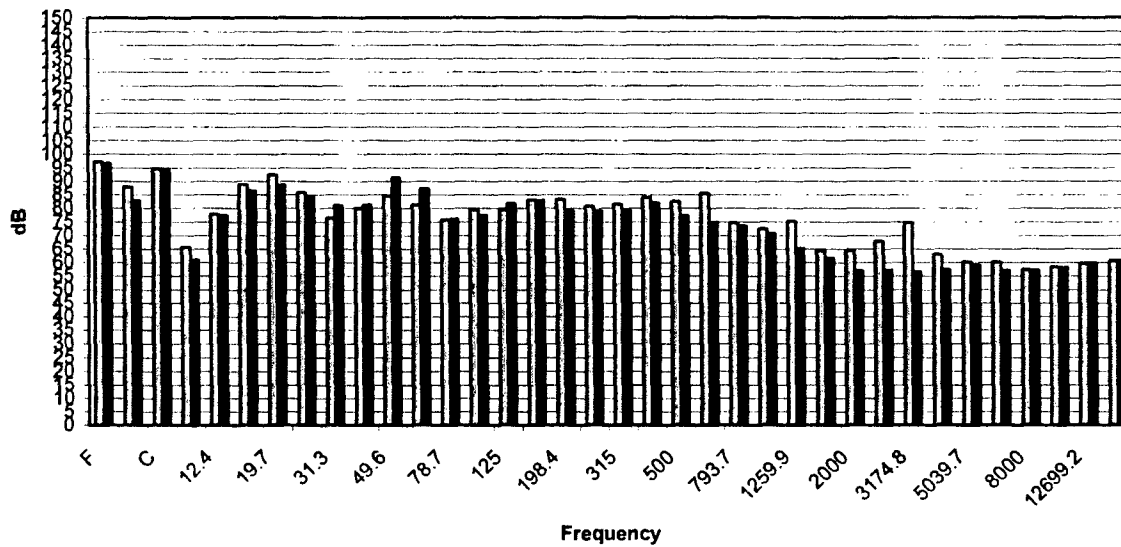
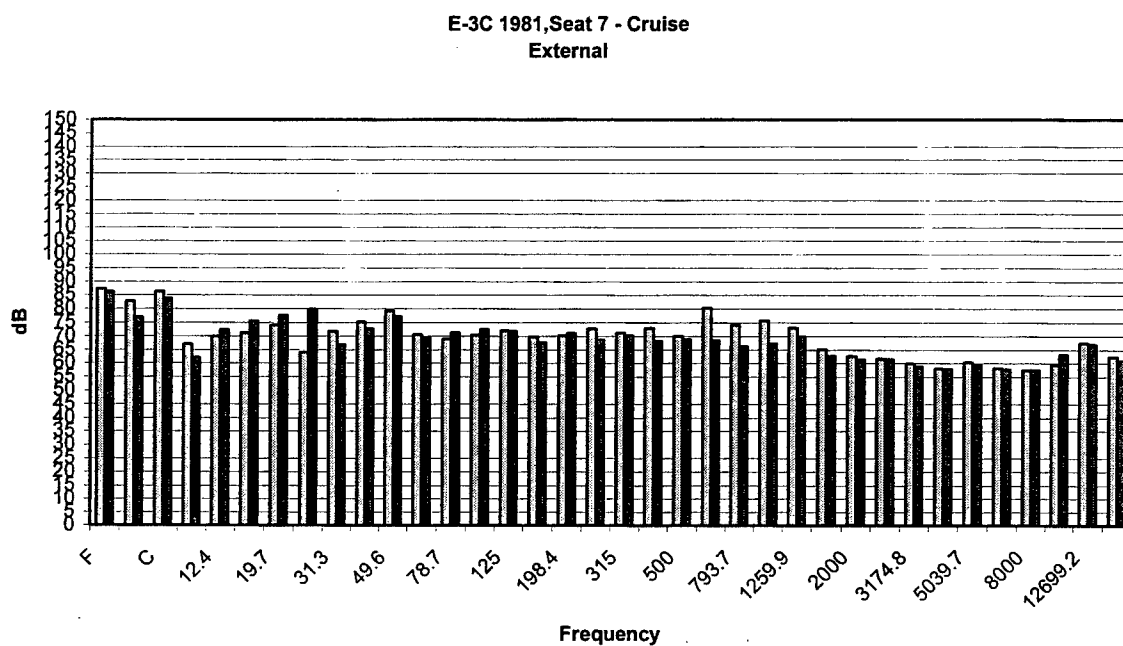
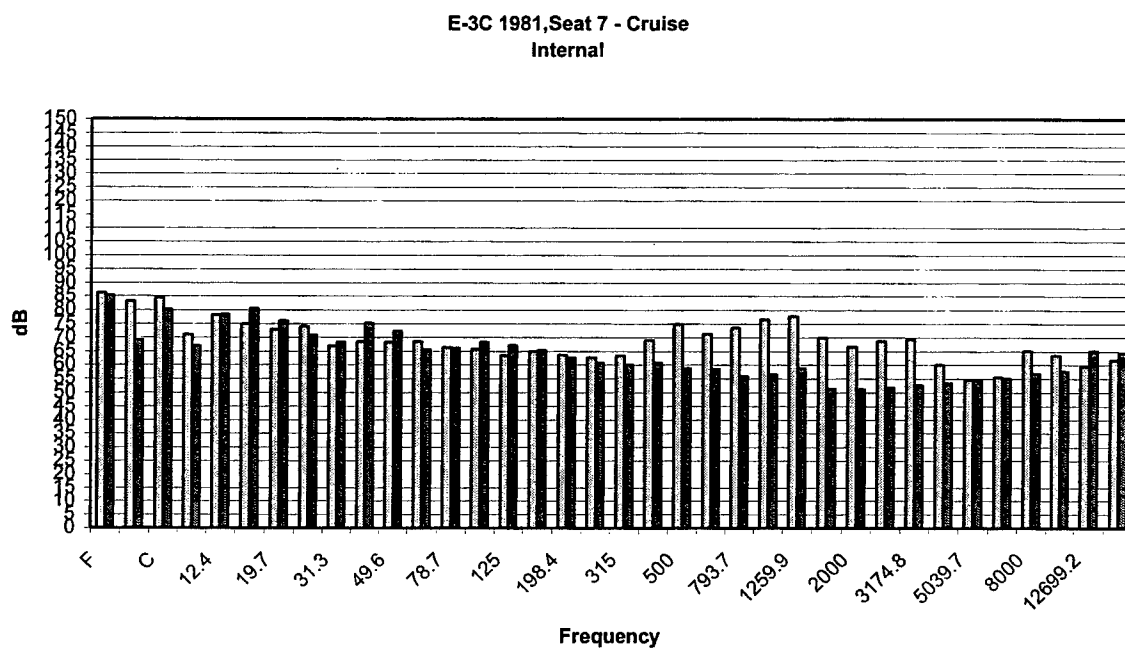
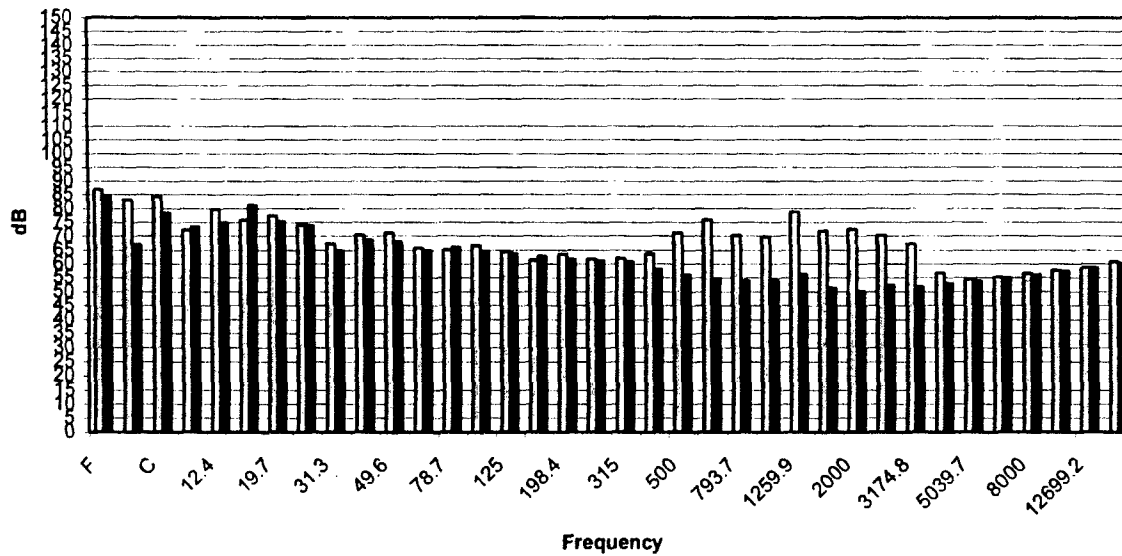


Figure 8. Internal and External Spectral Data for Condition 6 (Conventional Passive Headset)



**Figure 9. Internal and External Spectral Data for Condition 7 (Conventional Passive Headset)**

E-3C 1981, Seat 14 - Cruise  
Internal



E-3C 1981, Seat 14 - Cruise  
External

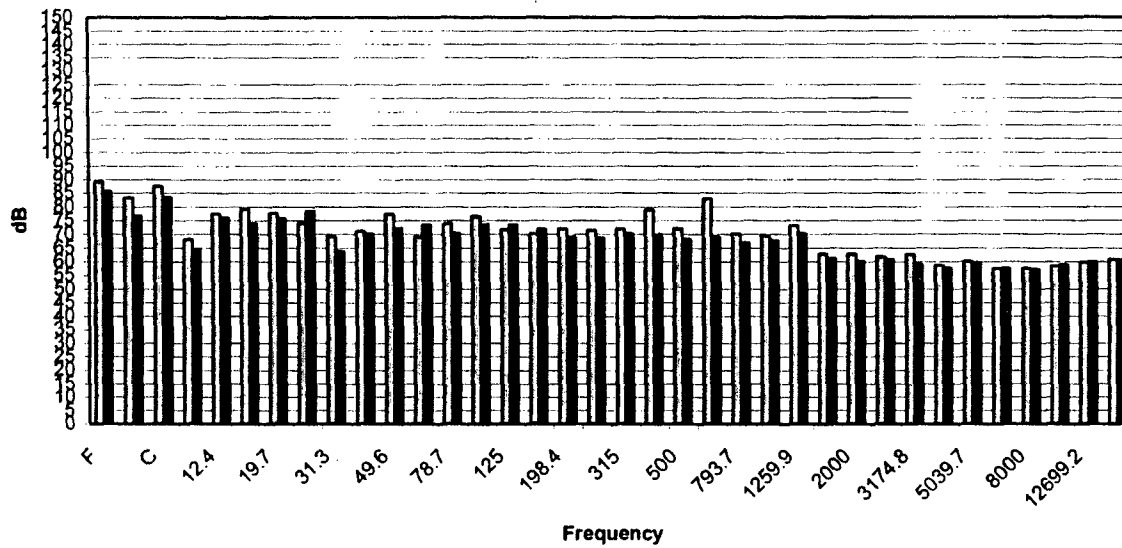
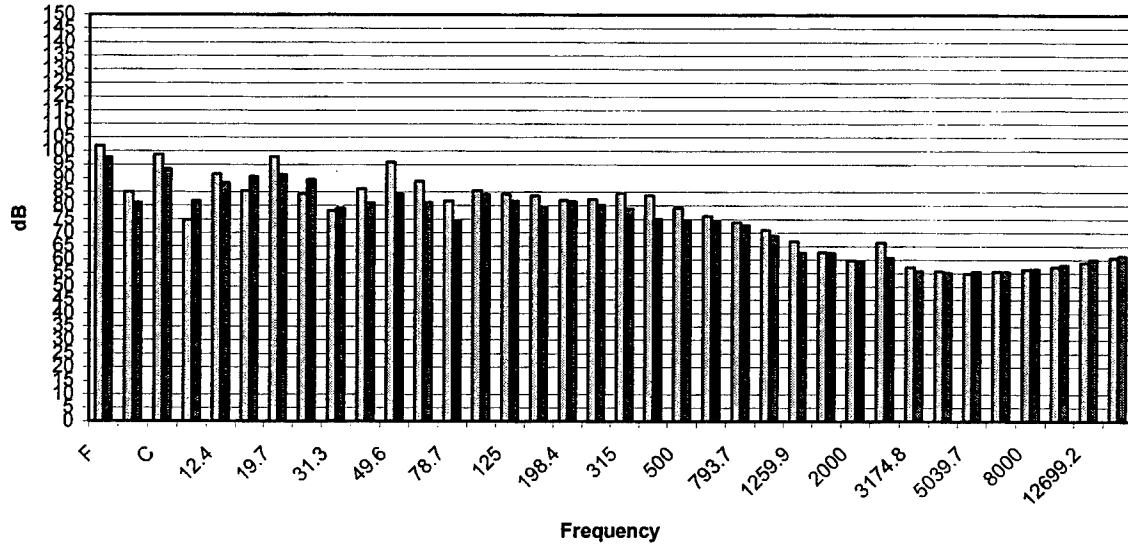


Figure 10. Internal and External Spectral Data for Condition 8 (Conventional Passive Headset)



E-3C 1981,Below Deck - Cruise  
Internal



E-3C 1981,Below Deck - Cruise  
External

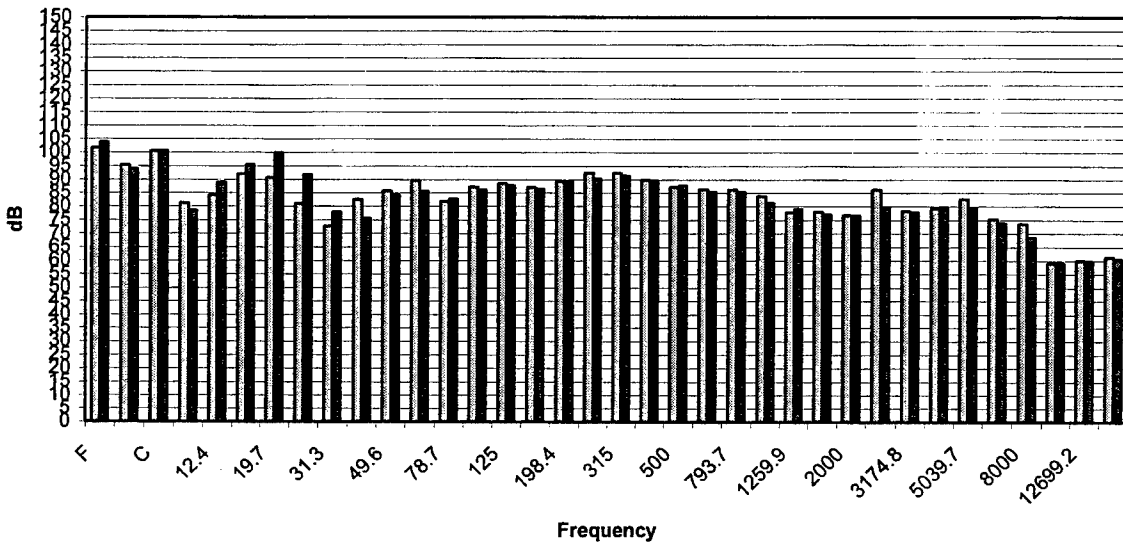
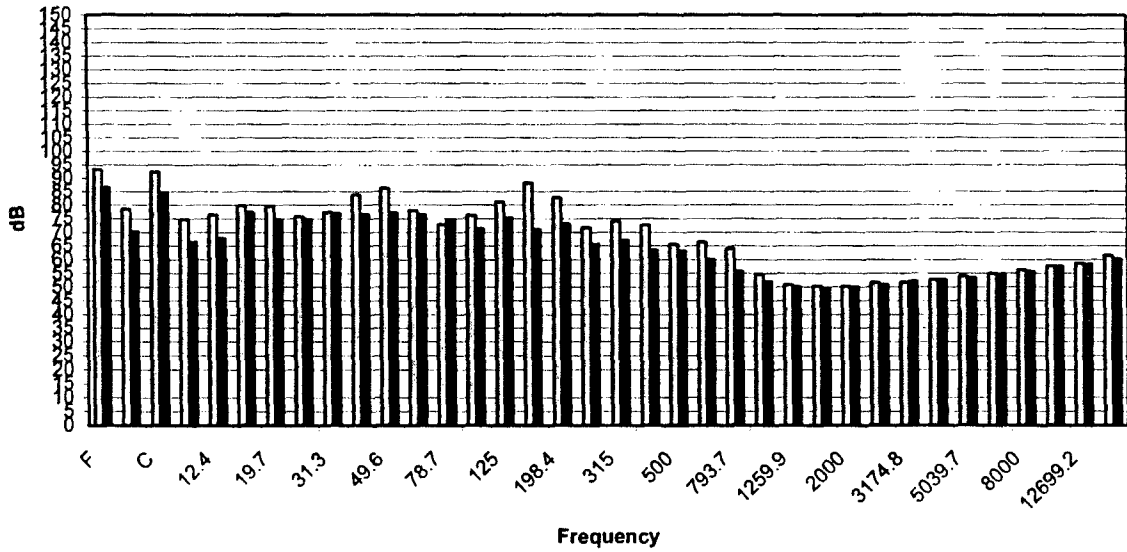


Figure 11. Internal and External Spectral Data for Condition 9 (Conventional Passive Headset)

E-3C 1981, Bed bunks (back bay) - Cruise  
Internal



E-3C 1981, Bed bunks (back bay) - Cruise  
External

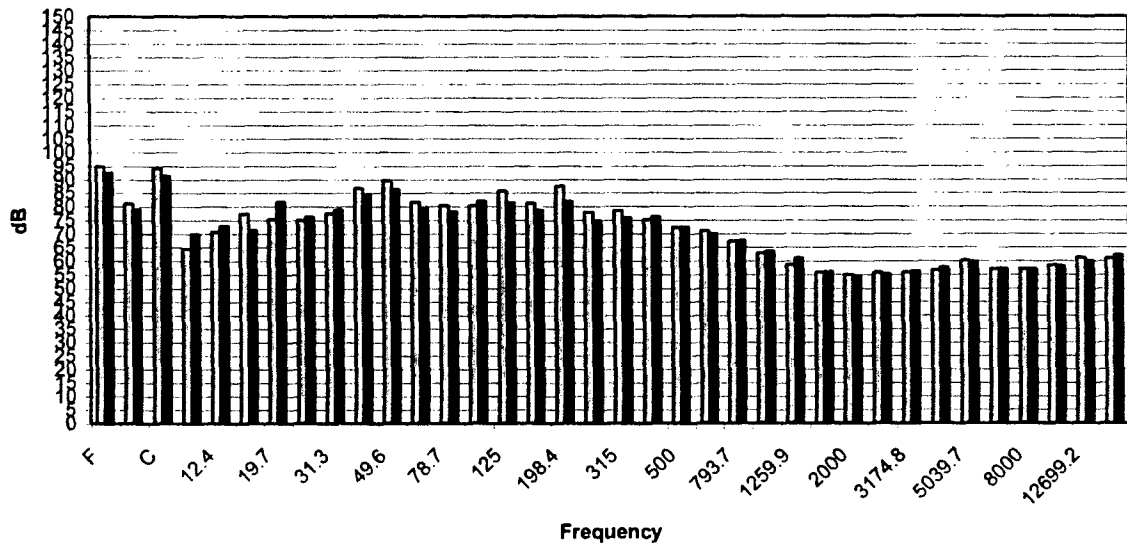


Figure 12. Internal and External Spectral Data for Condition 10 (Conventional Passive Headset)

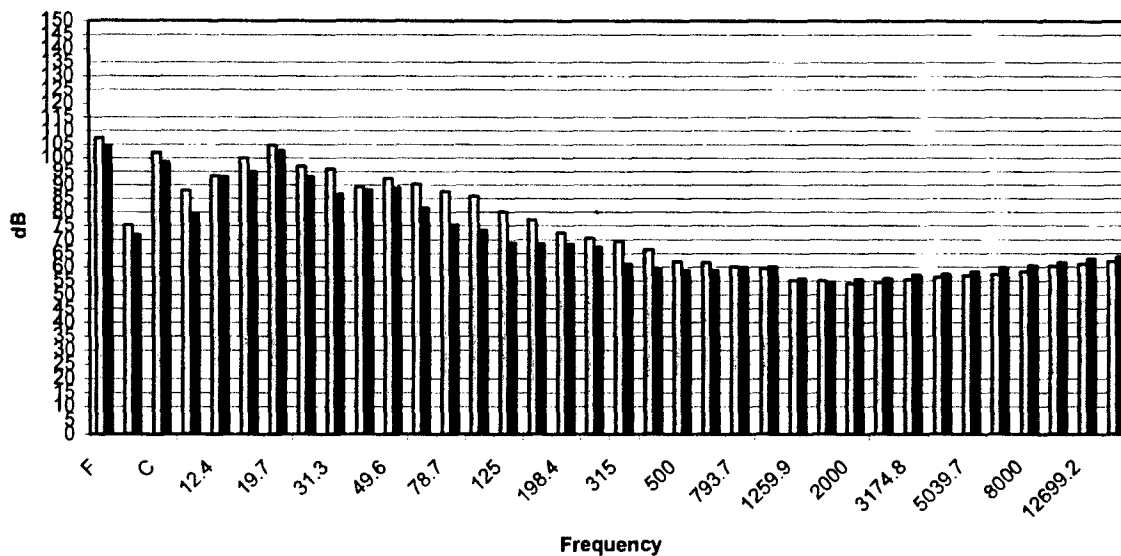
*Maximum Time Aircrew Can Remain in an Environment, For David Clark 1076 Passive Headset*

**Table 3. Internal Measured Levels and Maximum Times for the David Clark 1076 Passive Headset.**

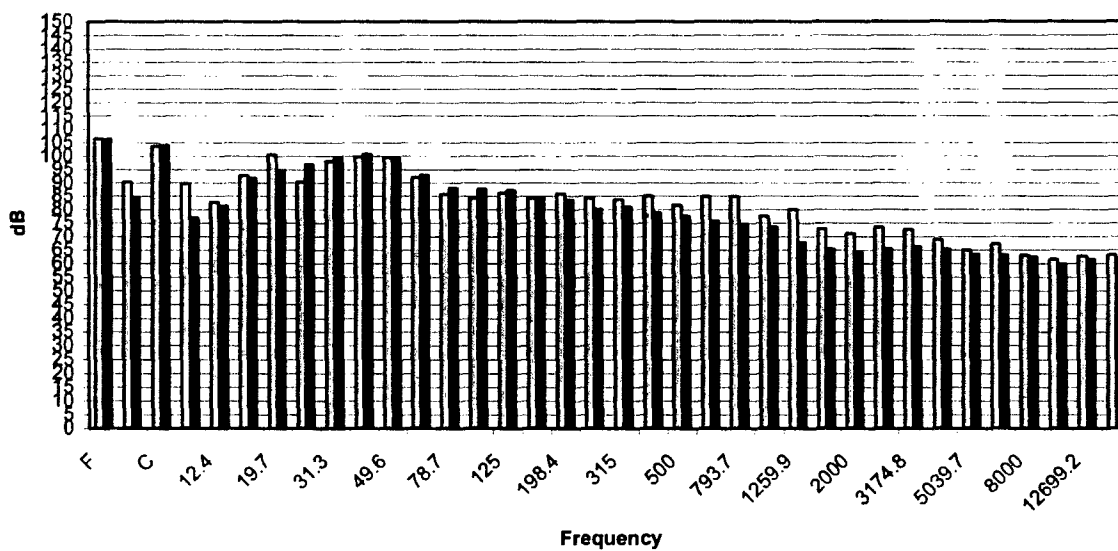
Condition #	Condition Description	Level			Time (hr)		
		Max.	Min.	Avg.	Max.	Min.	Avg.
1	Observer Seat 5 - Taxi	84.9	70.0	74.9	8.2	256.0	81.8
2	Observer Seat 5 - Takeoff	70.3	68.9	69.6	238.9	333.9	283.8
3	Observer Seat 5 - Climb	71.7	68.7	69.7	173.6	342.5	271.7
4	Observer Seat 5 - Cruise	69.9	67.3	68.2	260.8	477.7	384.7
5	Seat 7 - Cruise	83.1	69.0	75.3	12.4	319.6	74.9
6	Seat 11 - Cruise	84.9	72.6	77.1	8.3	139.7	49.2
7	Seat 14 - Cruise	83.1	67.2	74.8	12.4	485.5	84.7
8	Seat 25 - Cruise	70.1	68.6	69.2	251.3	354.6	311.2
9	Below Deck - Cruise	85.1	81.2	83.2	7.9	19.4	12.1
10	Bed bunks (back bay) - Cruise	78.6	70.4	71.9	34.9	236.1	165.2

*In-Flight Spectral Data For David Clark 1076-XL ANR Headset*

**E-3C 1981,RJ-Climb-Back Bay- ANR On  
Internal**



**E-3C 1981,RJ-Climb-Back Bay- ANR Off  
Internal**



**Figure 13. Internal Spectral Data for Condition 11 (David Clark 1076-XL ANR Headset), showing ANR On and Off.**

E-3C 1981,RJ-Climb-Back Bay- ANR Off  
External

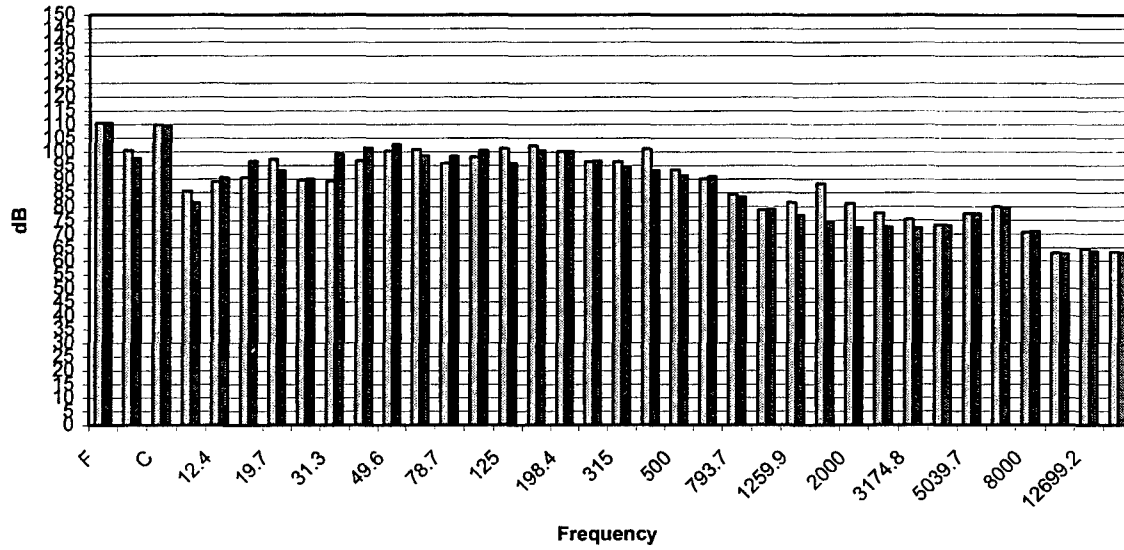
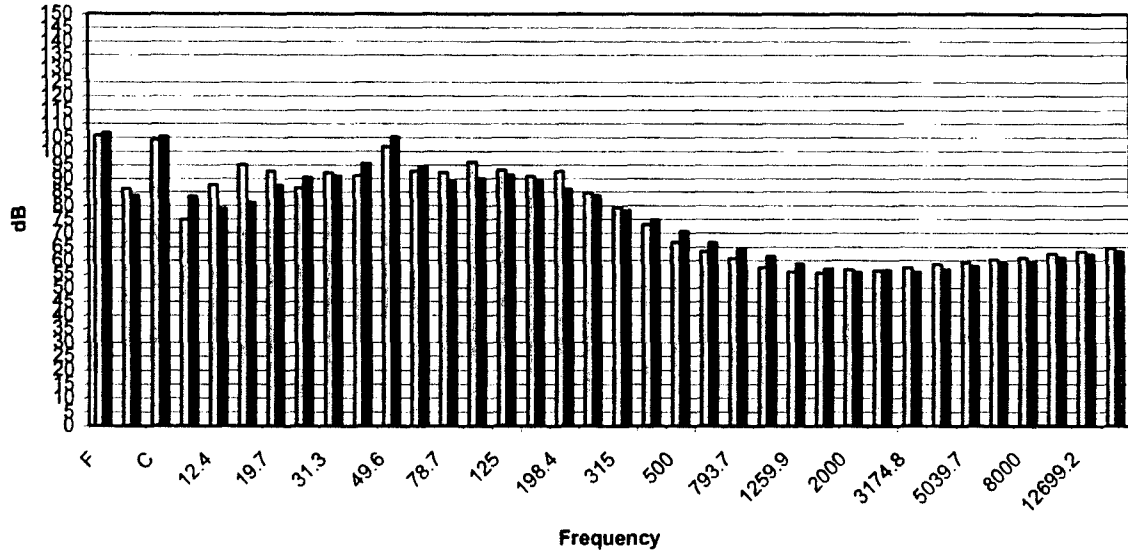


Figure 14. External Spectral Data for Condition 11 (David Clark 1076-XL ANR Headset).

E-3C 1981,RJ-Cruise-Back Bay- ANR Off  
Internal



E-3C 1981,RJ-Cruise-Back Bay- ANR On  
Internal

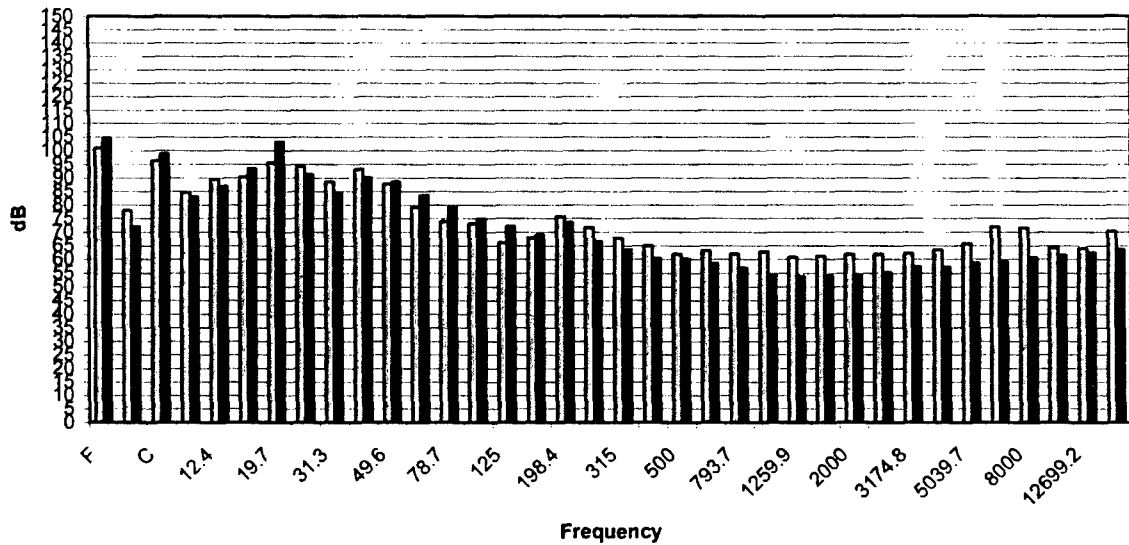


Figure 15. Internal Spectral Data for Condition 12 (David Clark 1076-XL ANR Headset), showing ANR On and Off.

E-3C 1981,RJ-Cruise-Back Bay- ANR On  
External

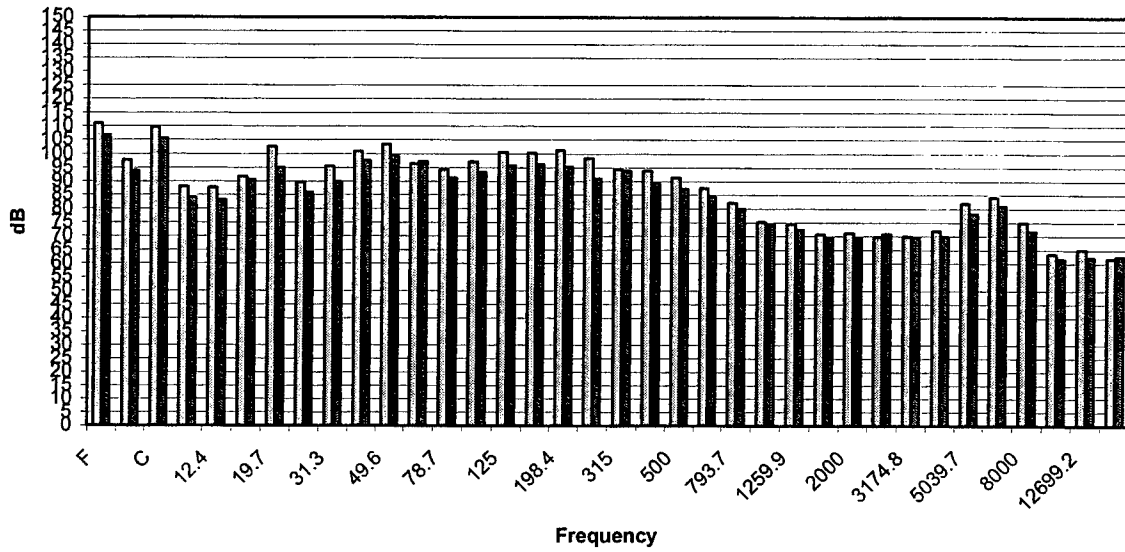
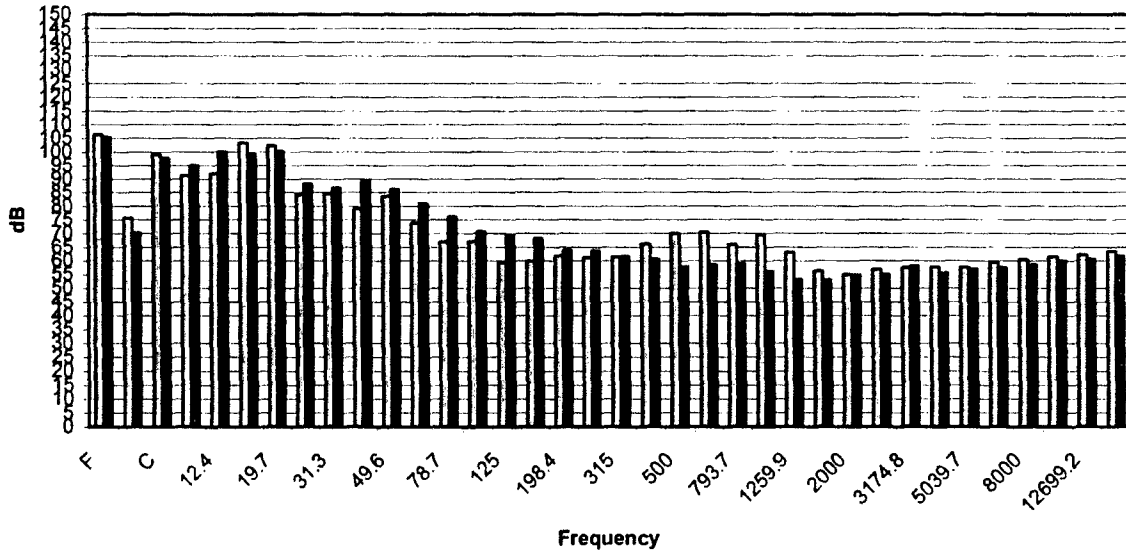


Figure 16. External Spectral Data for Condition 12 (David Clark 1076-XL ANR Headset).

E-3C 1981,RJ-Cruise-Seat 25- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 25- ANR Off  
Internal

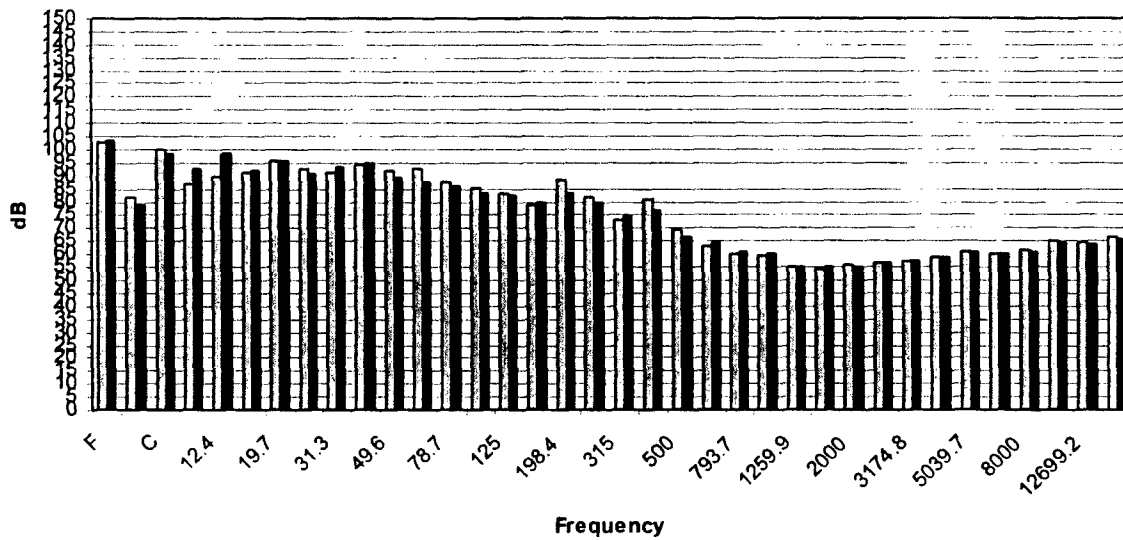


Figure 17. Internal Spectral Data for Condition 13 (David Clark 1076-XL ANR Headset), showing ANR On and Off.



E-3C 1981,RJ-Cruise-Seat 25- ANR Off  
External

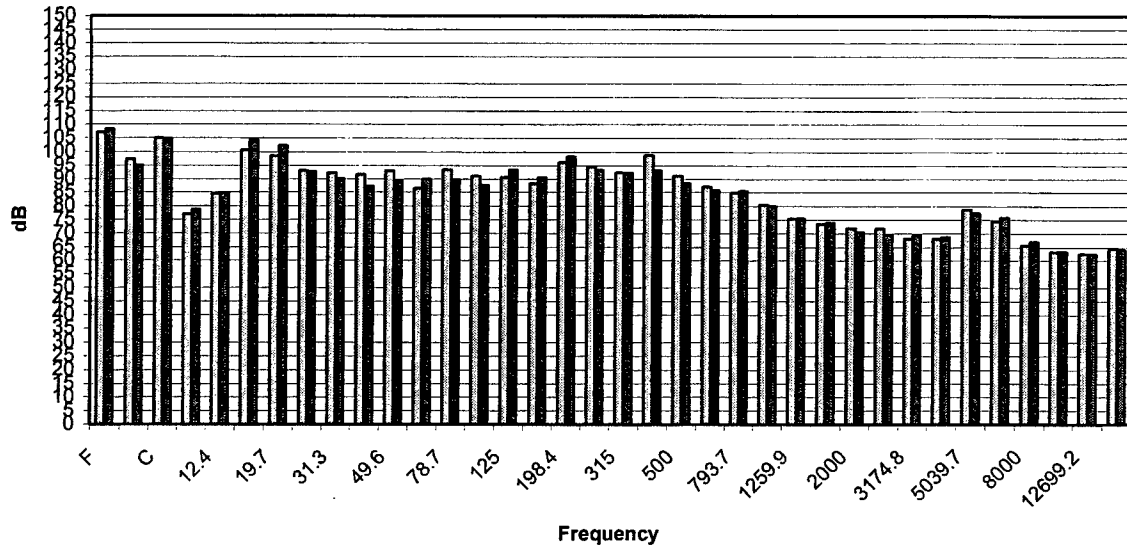
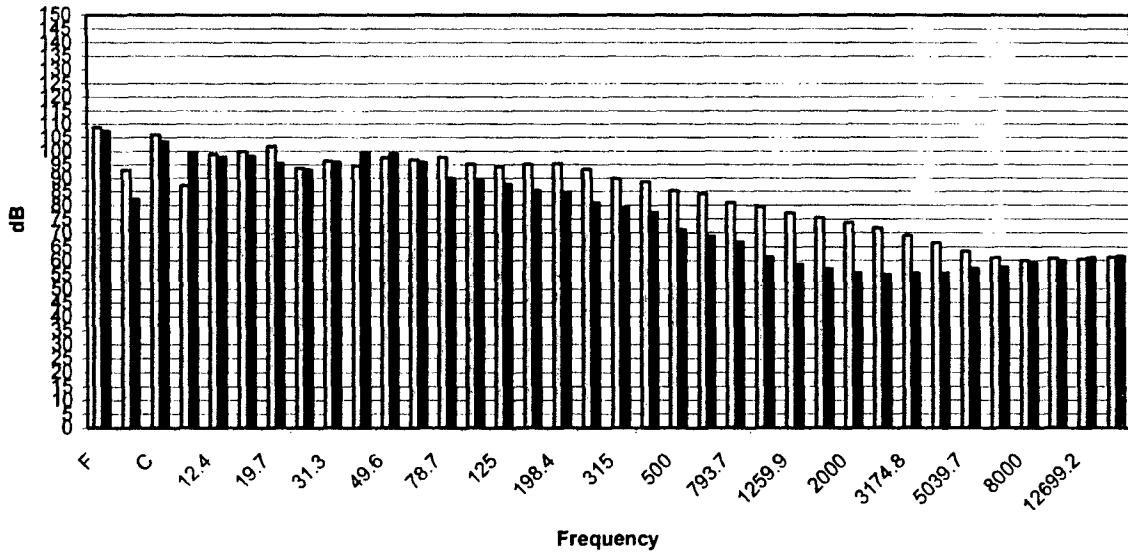


Figure 18. External Spectral Data for Condition 13 (David Clark 1076-XL ANR Headset).

E-3C 1981,RJ-Cruise-BelowDeck- ANR Off  
Internal



E-3C 1981,RJ-Cruise-BelowDeck- ANR Off  
External

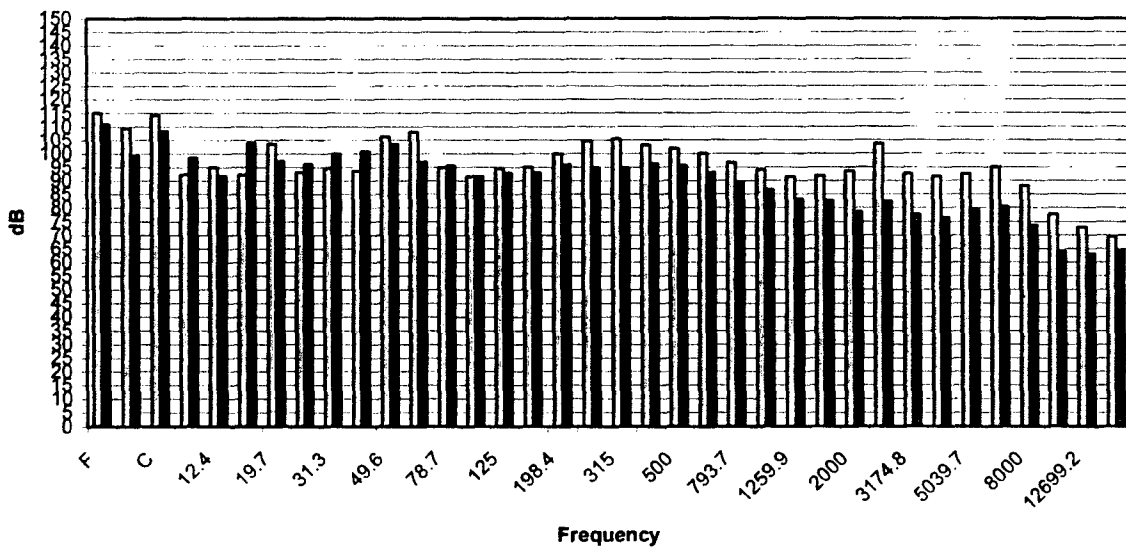
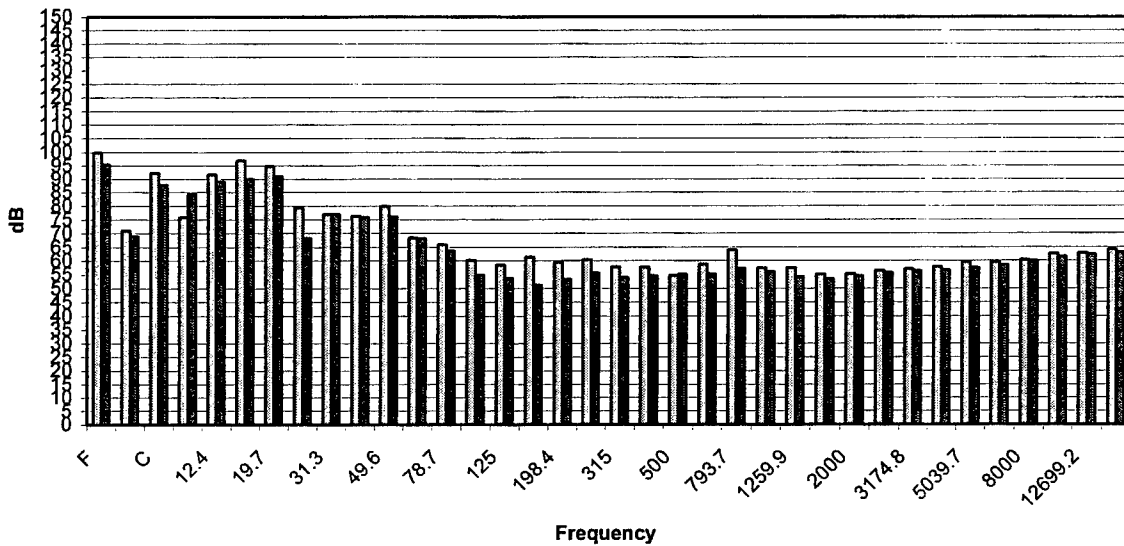


Figure 19. Internal and External Spectral Data for Condition 14 (David Clark 1076-XL ANR Headset)

E-3C 1981,RJ-Cruise-Seat 11- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 11- ANR Off  
Internal

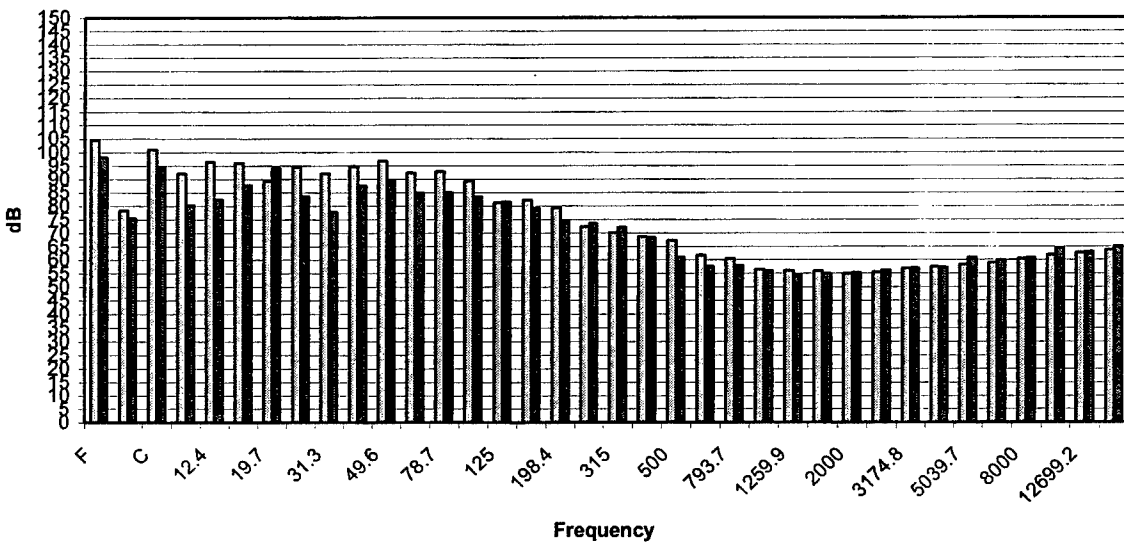


Figure 20. Internal Spectral Data for Condition 15 (David Clark 1076-XL ANR Headset), showing ANR On and Off.

E-3C 1981,RJ-Cruise-Seat 11- ANR O  
External

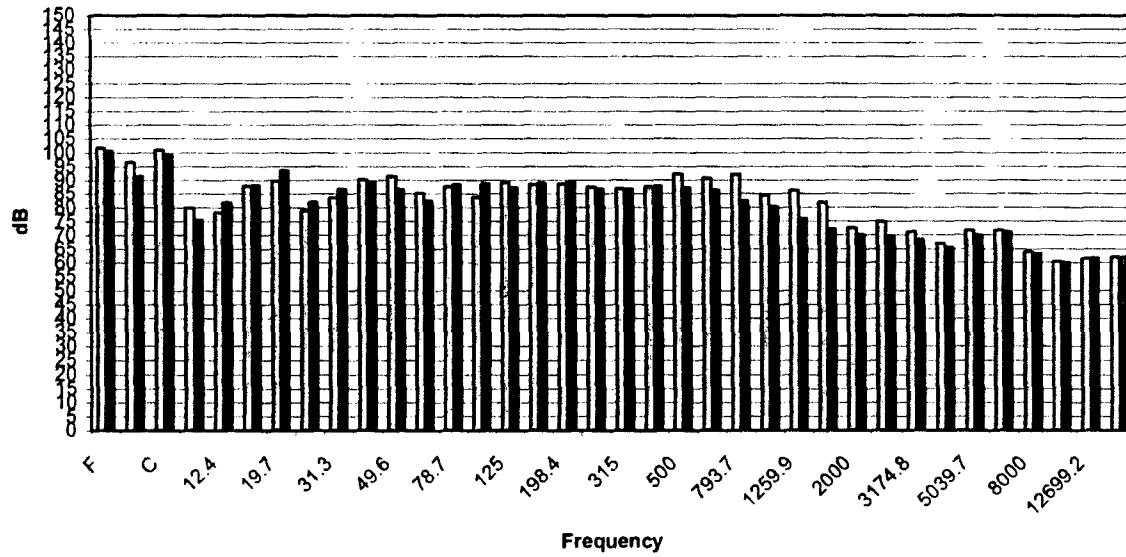
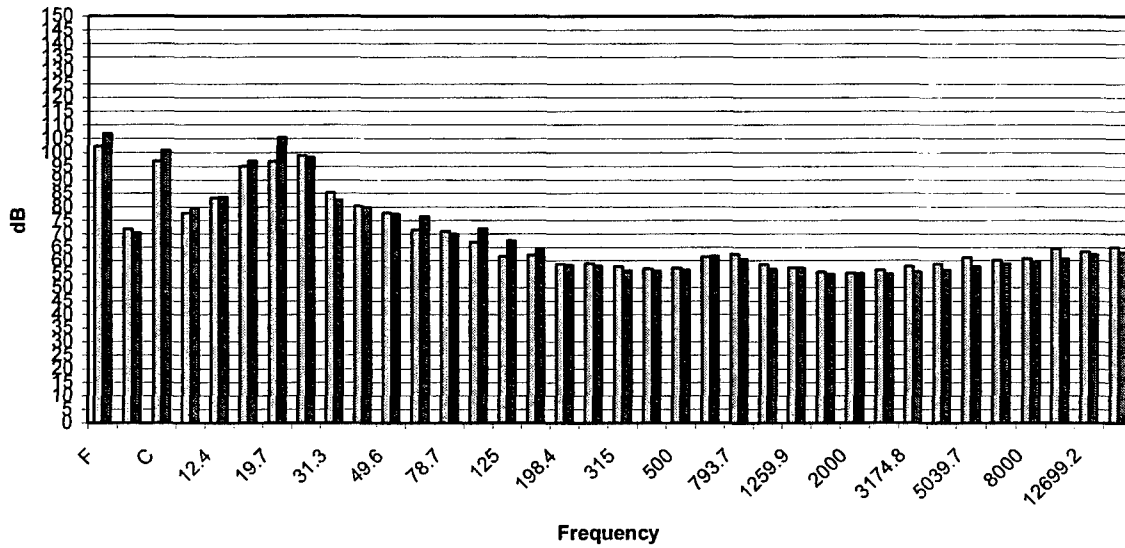


Figure 21. External Spectral Data for Condition 15 (David Clark 1076-XL ANR Headset).

E-3C 1981,RJ-Cruise-Seat 7- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 7- ANR Off  
Internal

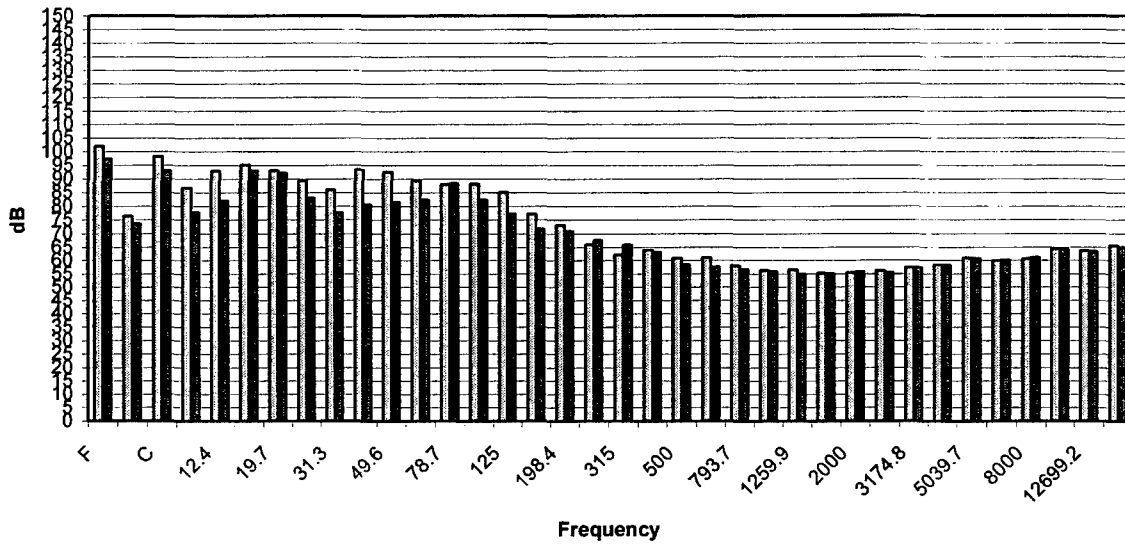


Figure 22. Internal Spectral Data for Condition 16 (David Clark 1076-XL ANR Headset), showing ANR On and Off.

E-3C 1981,RJ-Cruise-Seat 7- ANR On  
External

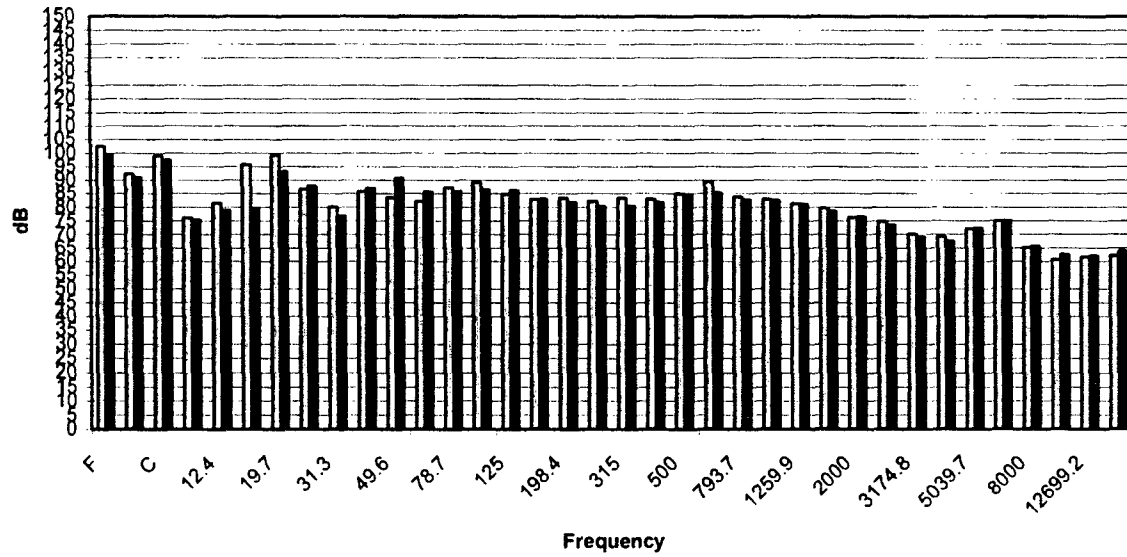
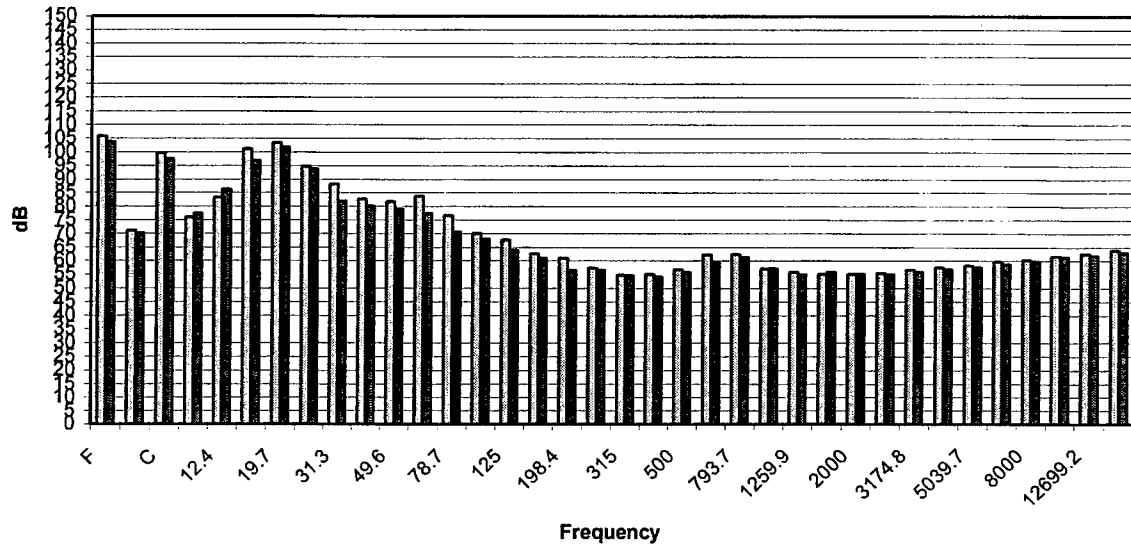


Figure 23. External Spectral Data for Condition 16 (David Clark 1076-XL ANR Headset).

E-3C 1981,RJ-Cruise-Seat 24- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 24- ANR Off  
Internal

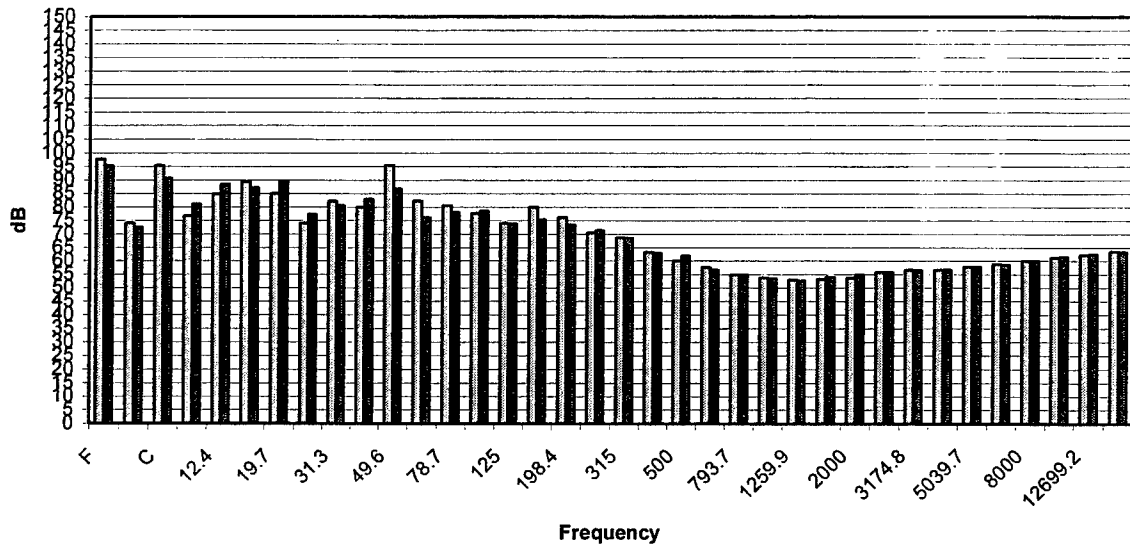


Figure 24. Internal Spectral Data for Condition 17 (David Clark 1076-XL ANR Headset), showing ANR On and Off.

E-3C 1981,RJ-Cruise-Seat 24- ANR Off  
External

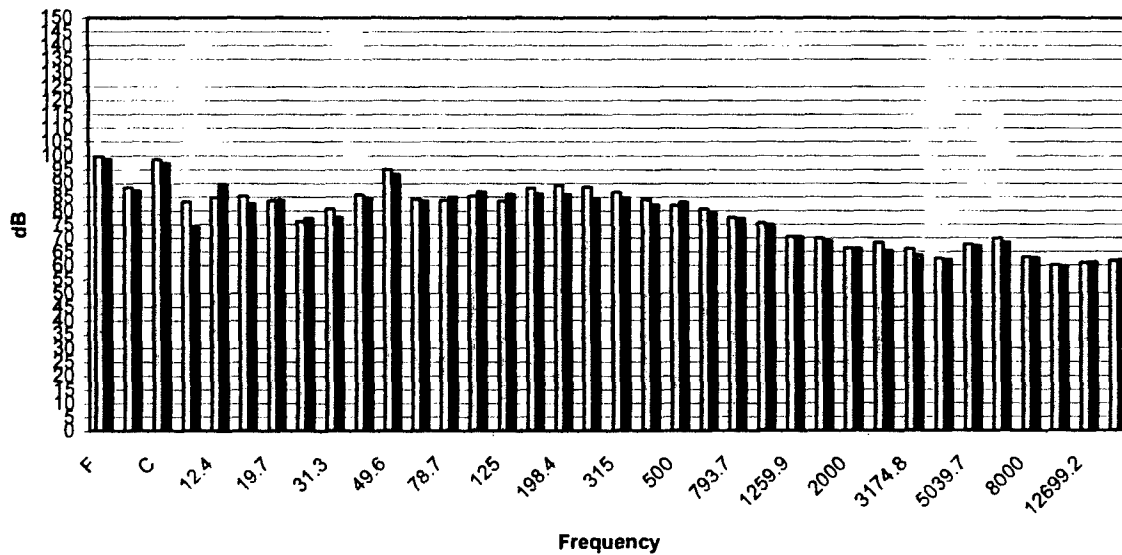


Figure 25. External Spectral Data for Condition 17 (David Clark 1076-XL ANR Headset).



*Exposure Levels For David Clark 1076-XL ANR Headset*

**Table 4. Internal Measured Levels and Maximum Times for the David Clark 1076-XL ANR Headset.**

Condition #	Description	Level (dBA)			Time (hr)		
		Max.	Min.	Avg.	Max.	Min.	Avg.
11	Climb-Back Bay- ANR Off	90.4	85.4	87.0	2.3	7.3	5.0
11	Climb-Back Bay- ANR On	74.5	71.8	73.4	89.7	167.3	118.0
12	Cruise-Back Bay- ANR Off	86.2	83.8	85.2	6.1	10.6	7.6
12	Cruise-Back Bay- ANR On	78.0	72.1	73.1	39.9	159.0	125.3
13	Cruise-Seat 25- ANR Off	82.2	79.3	81.1	15.2	29.8	19.8
13	Cruise-Seat 25- ANR On	74.3	70.4	71.7	95.4	235.6	171.6
14	Cruise-Below Deck- ANR Off	93.1	82.2	87.3	1.2	15.1	4.7
15	Cruise-Seat 11- ANR Off	78.4	75.6	76.7	36.9	70.0	54.0
15	Cruise-Seat 11- ANR On	71.0	69.3	70.1	202.7	299.6	250.6
16	Cruise-Seat 7- ANR Off	76.0	73.6	74.8	63.6	110.4	83.8
16	Cruise-Seat 7- ANR On	71.8	71.1	71.5	170.1	199.5	179.7
17	Cruise-Seat 24- ANR Off	74.1	72.6	73.5	99.7	140.4	114.3
17	Cruise-Seat 24- ANR On	71.1	70.1	70.7	196.7	253.1	219.1

## DISCUSSION

The taxi, takeoff, and climb conditions were found to not be a significant factor in the exposure for the crewmember at observer seat 5. The exposure for these events was low due to the short duration of the condition. It was deemed unnecessary to obtain the noise levels for these conditions at other locations in the aircraft because of the low exposure.

The data in Table 3 show that there is only one location where the current hearing protection, the David Clark 1076, does not permit the aircrew to fly for 24 hours of cruise. This is the area below the deck. From conversations that followed the collection of the data, it was mentioned that the aircrew would spend very little time in this area during a flight. In the case of the David Clark 1076-XL ANR Headset, Table 4 shows that the aircrew may not be located at seat 24, below the deck, or in the Back Bay for an entire 24-hour flight with just the passive attenuation of the headset. It is noticed that the time was significantly increased when the ANR circuit was turned on.

Data were collected for both headsets at seats 7, 11, and 25. For seats 7 and 11 the average values for the ANR off and the passive headset are similar. In this case the ANR circuit provided protection that increased the maximum time for the aircrew by two to four times.



**Figure 26. An Example of the Net4 Condition.**



**Figure 27. Another Example of the Net4 Condition.**

It is important to point out that during data collection the headsets were worn over the ear with the internal microphone throughout the entire mission. However, during actual E-3 sorties many mission crewmembers temporarily remove the headset from one ear to better hear neighboring crewmembers. This phenomenon would result in increased exposure (look in Appendix C for calculations of this "Net 4" condition and how it affects the exposure). From the data in Appendix C it is clear that the ear not protected is exposed to much more noise that can cause auditory damage. The limiting item, then, is the shortest time.

Finally, the non-auditory effects of noise such as increased fatigue and ambient noise impact on voice communications and situational awareness were not studied in this project.

## **CONCLUSIONS**

### **CAVEATS**

Since two separate man-mounted recording devices were used, the data recorded by the devices in corresponding locations showed some variance. This is due to dynamic acoustic changes in the in-flight noise signature for similar locations when data were captured at different times in the mission (each recording device was not at the exact same time and condition in the mission). One example is flying with the wind on the outward leg and into the wind on the return leg of the mission. The noise levels were not corrected to ensure that the response of the Knowles BL-1785 microphone is flat. Furthermore, these data were captured on only two individuals during a specific mission profile. The recordings are therefore a "snapshot" of what we believe is the typical in-flight noise environment aboard a typical E-3.

### **COMPARISON**

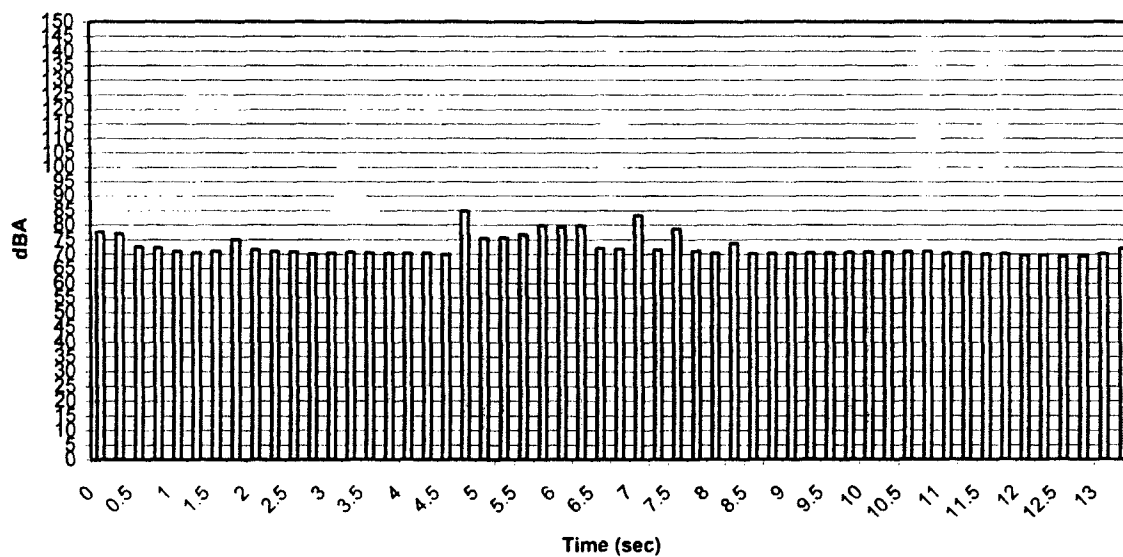
Tables 3 and 4 show that there are a few places in the aircraft where the crewmember is exposed to the maximum allowed dose within the mission (exposures over 1.0 are bolded). These tables show that the exposures were reduced through the use of the David Clark 1076-XL ANR headset. The reduction was significant for many crew locations.

### **RECOMMENDATIONS**

With the variation that was seen on the external data collected, it was determined that these recording systems are not sufficient to comprehensively characterize the ambient noise aboard the E-3 aircraft at all locations for all mission phases. AFRL/HECB recommends the aircraft be instrumented with a system that places microphones throughout the aircraft and records the noise levels synchronously. These data will be collected in a manner that will insure sufficient accuracy to predict the effect of the ANR headsets using the ANR attenuation data collected by AFRL/HECB (in accordance with ANSI Std. S12.42-1995) on commercially available ANR military headsets from a variety of manufacturers.

## Appendix A – In-flight Noise Time Histories

E-3C 1981, Observer Seat 5 - Taxi  
Internal



E-3C 1981, Observer Seat 5 - Taxi  
External

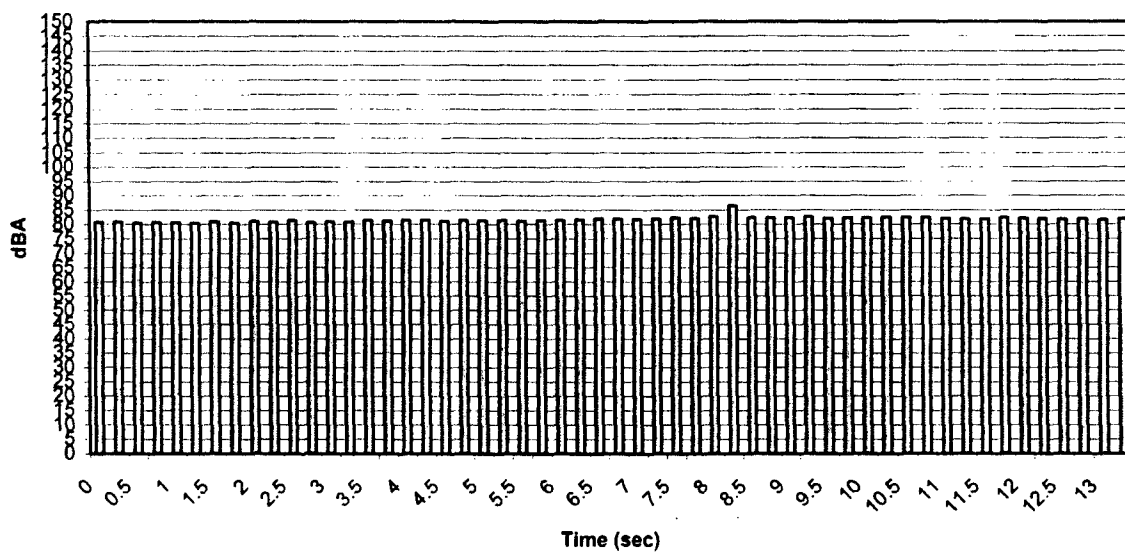
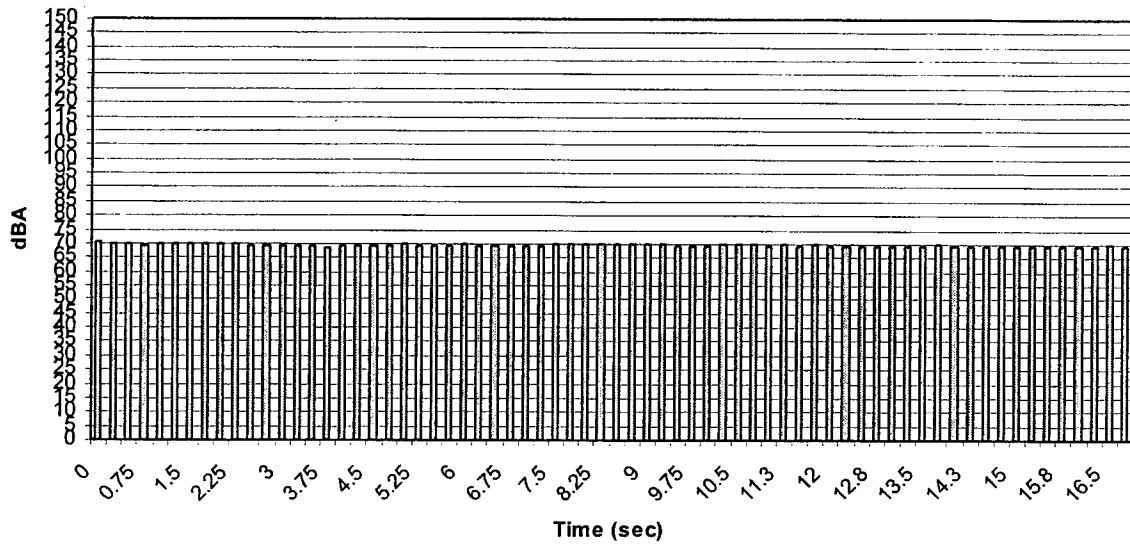


Figure A-1. Internal and External A-Weighted Time Histories for Condition 1.

E-3C 1981, Observer Seat 5 - Takeoff  
Internal



E-3C 1981, Observer Seat 5 - Takeoff  
External

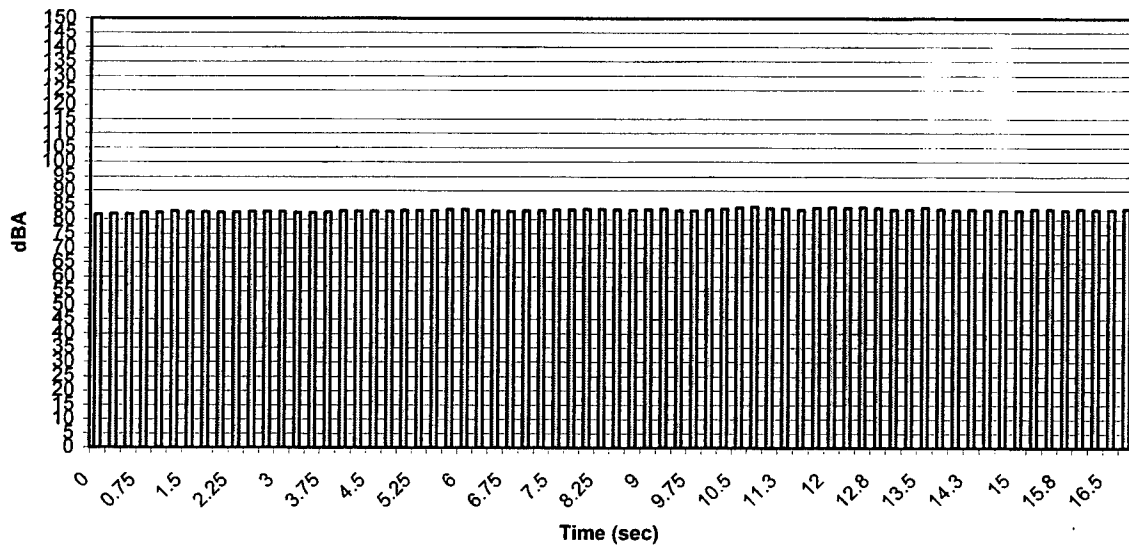
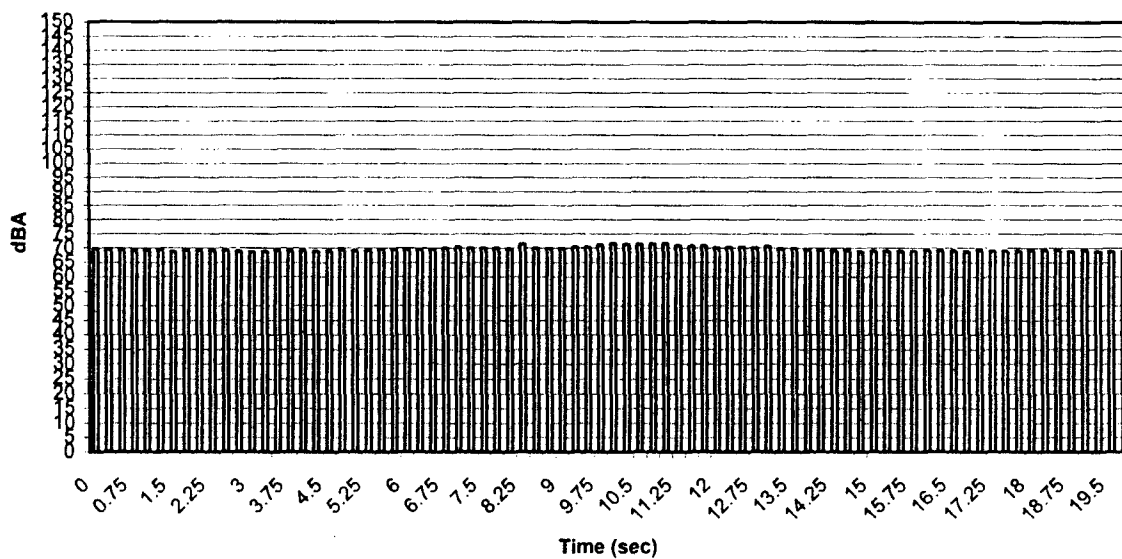


Figure A-2. Internal and External A-Weighted Time Histories for Condition 2.

E-3C 1981, Observer Seat 5 - Climb  
Internal



E-3C 1981, Observer Seat 5 - Climb  
External

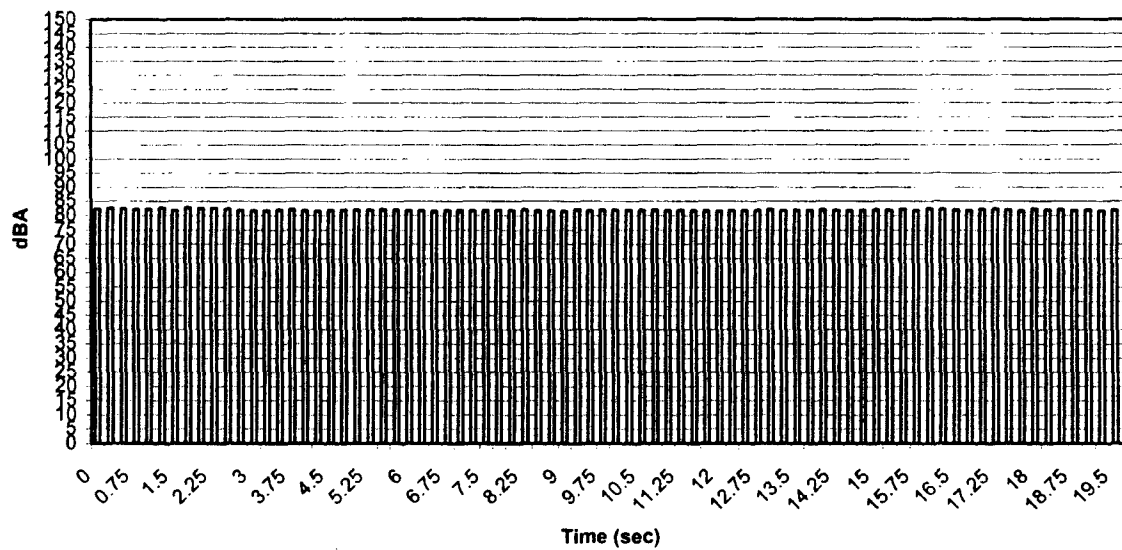
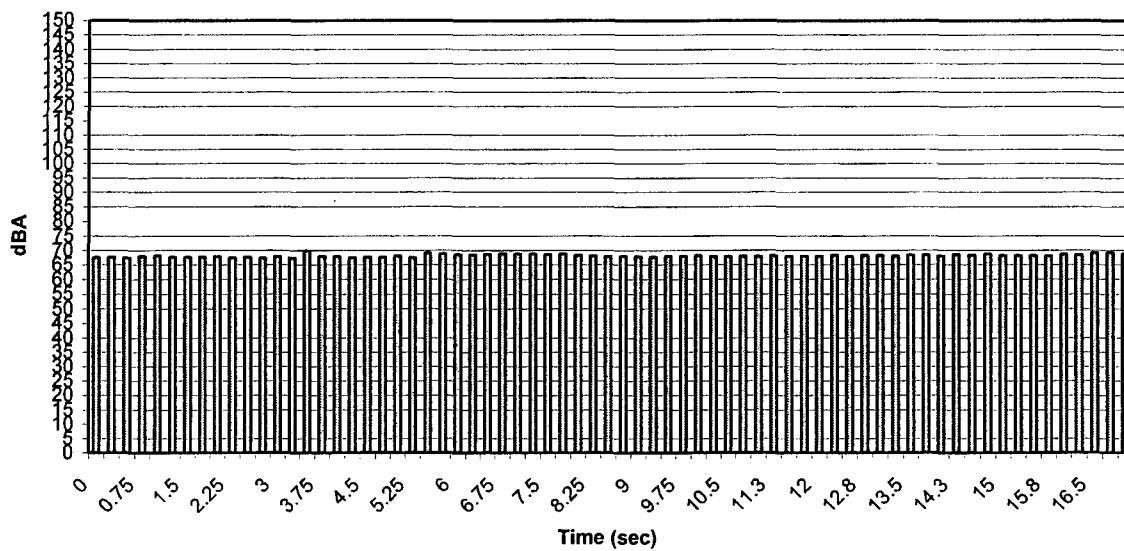


Figure A-3. Internal and External A-Weighted Time Histories for Condition 3.

E-3C 1981, Observer Seat 5 - Cruise  
Internal



E-3C 1981, Observer Seat 5 - Cruise  
External

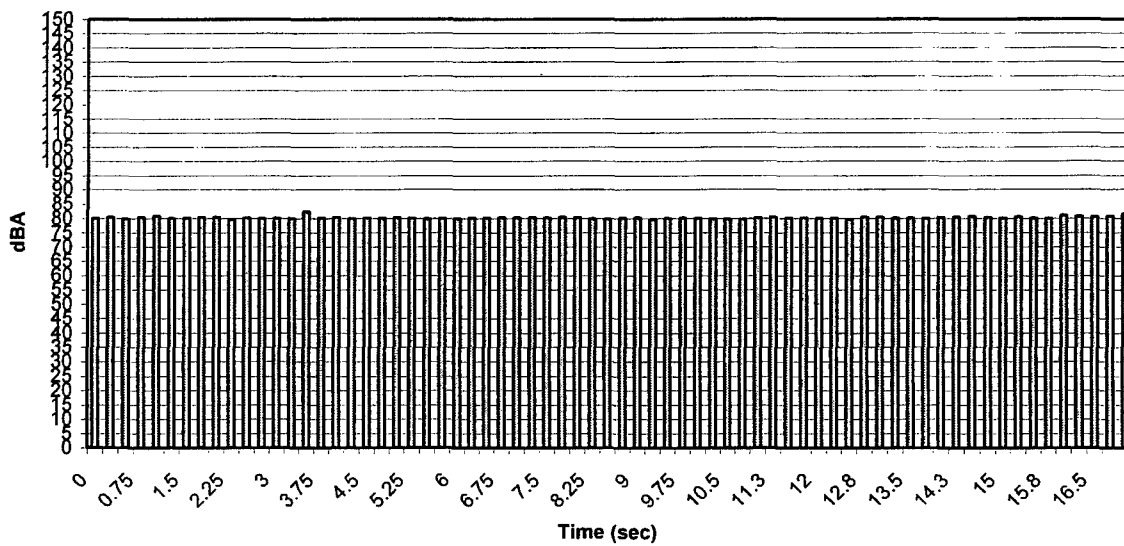
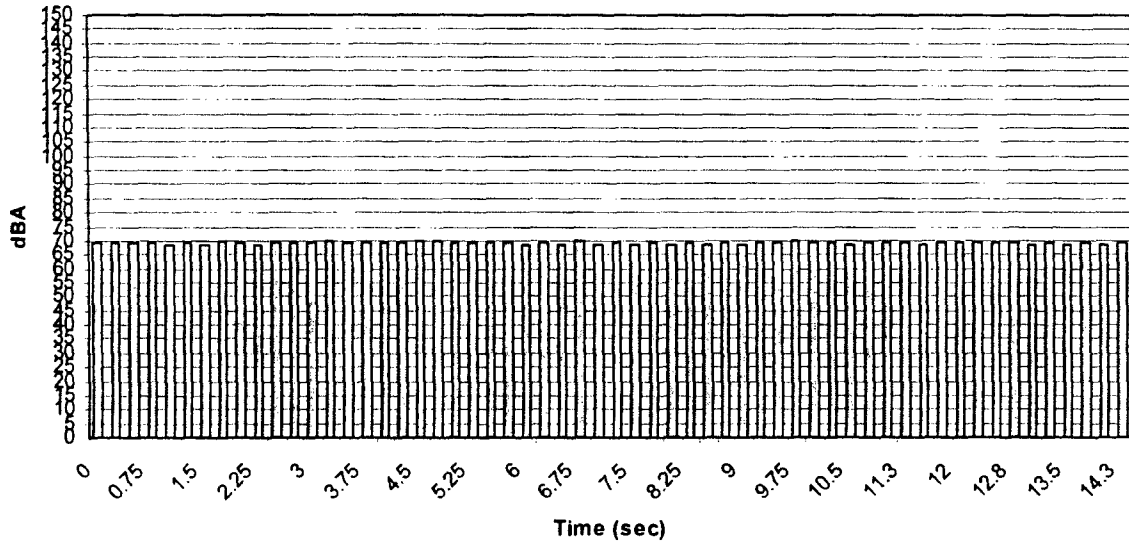


Figure A-4. Internal and External A-Weighted Time Histories for Condition 4.

E-3C 1981, Seat 25 - Cruise  
Internal



E-3C 1981, Seat 25 - Cruise  
External

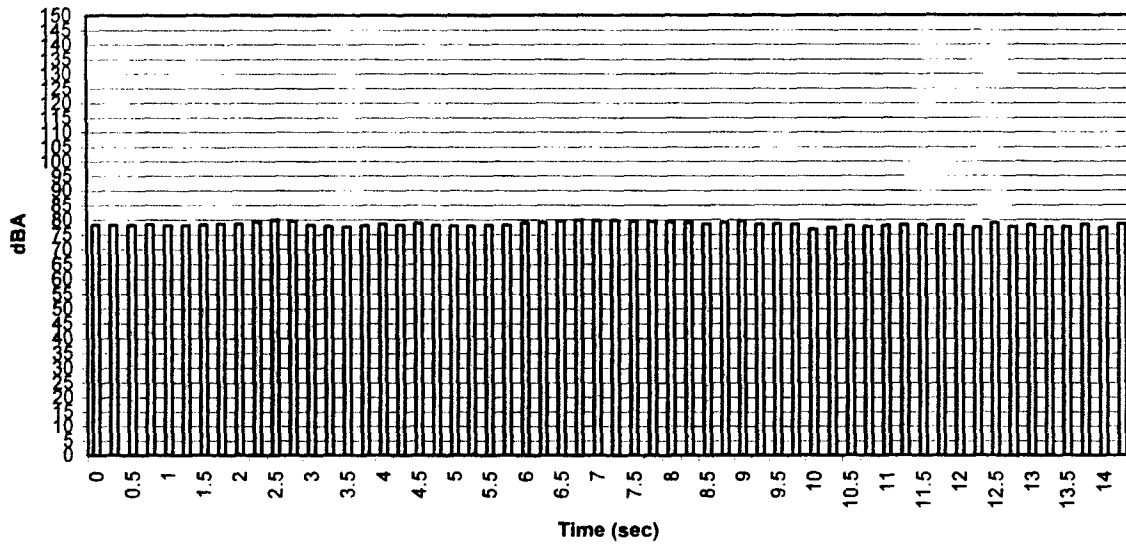
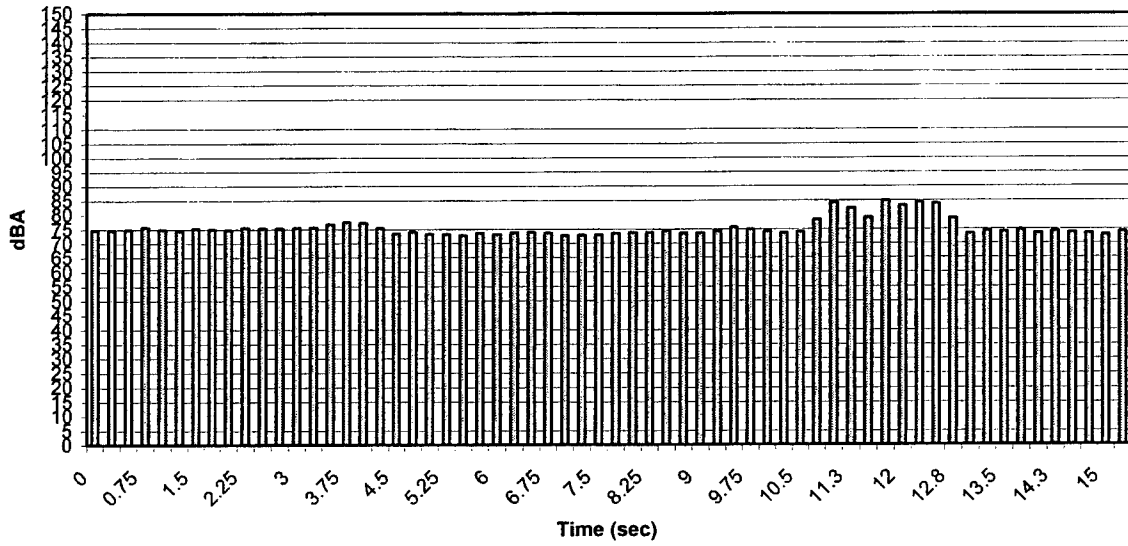


Figure A-5. Internal and External A-Weighted Time Histories for Condition 5.



E-3C 1981, Seat 11 - Cruise  
Internal



E-3C 1981, Seat 11 - Cruise  
External

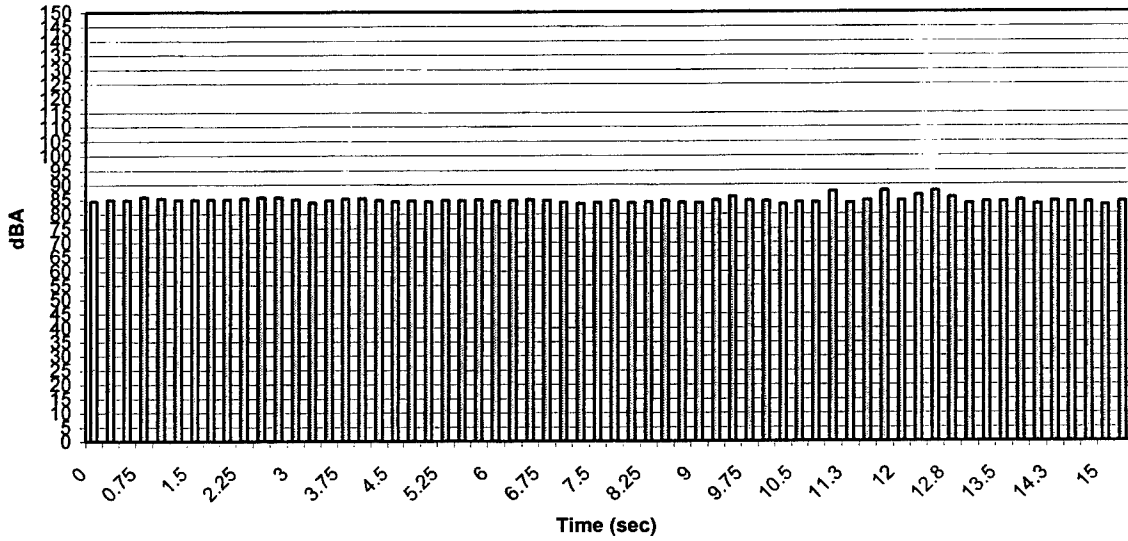
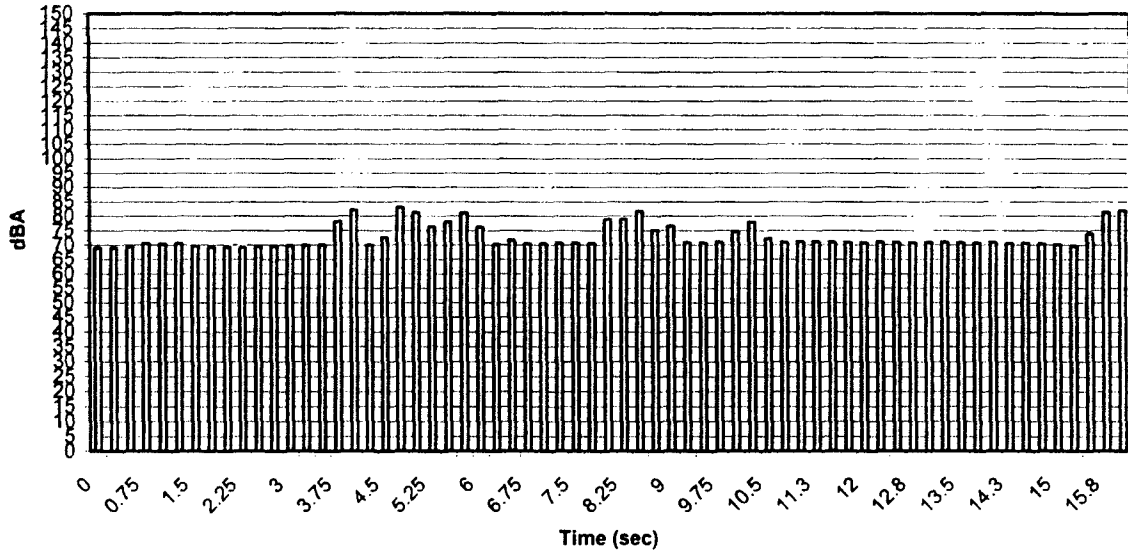


Figure A-6. Internal and External A-Weighted Time Histories for Condition 6.

E-3C 1981, Seat 7 - Cruise  
Internal



E-3C 1981, Seat 7 - Cruise  
External

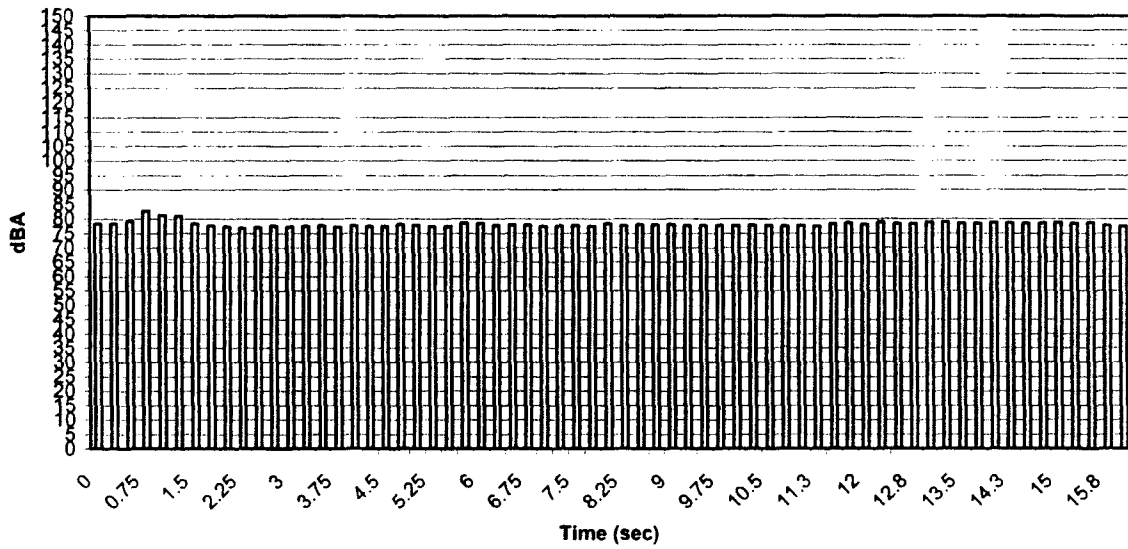
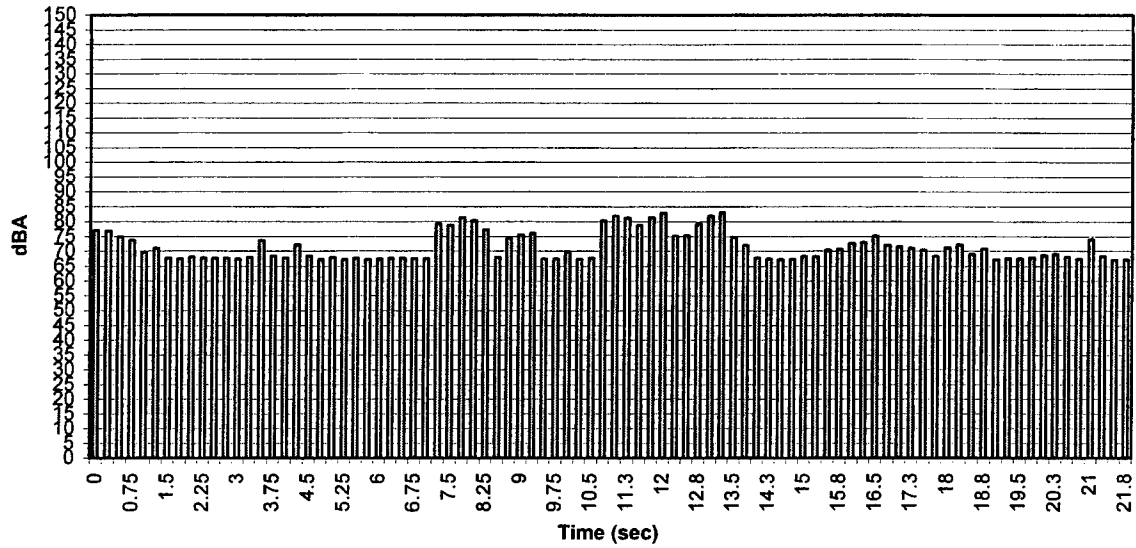


Figure A-7. Internal and External A-Weighted Time Histories for Condition 7.

E-3C 1981, Seat 14 - Cruise  
Internal



E-3C 1981, Seat 14 - Cruise  
External

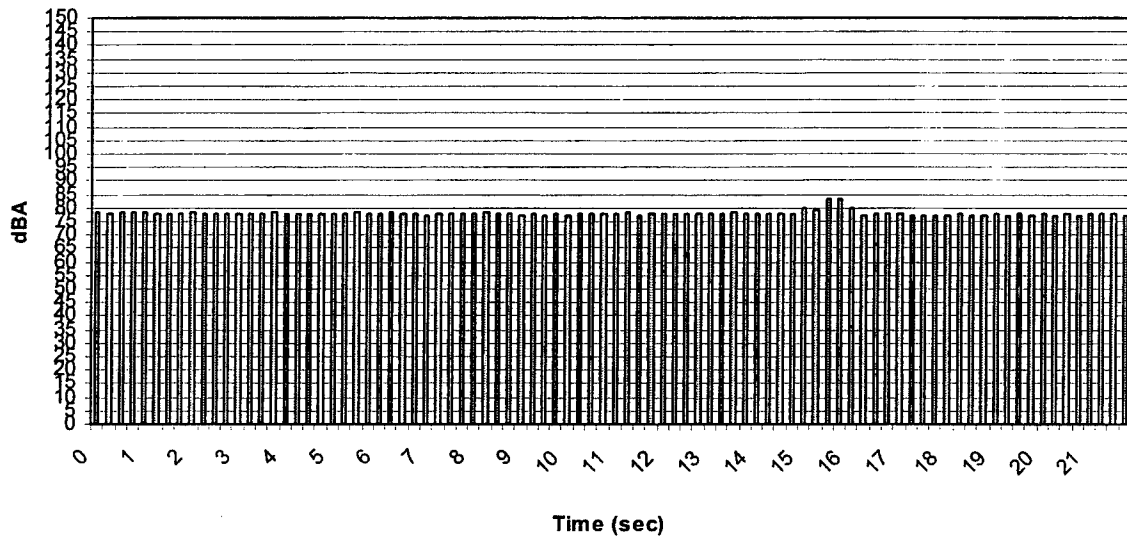
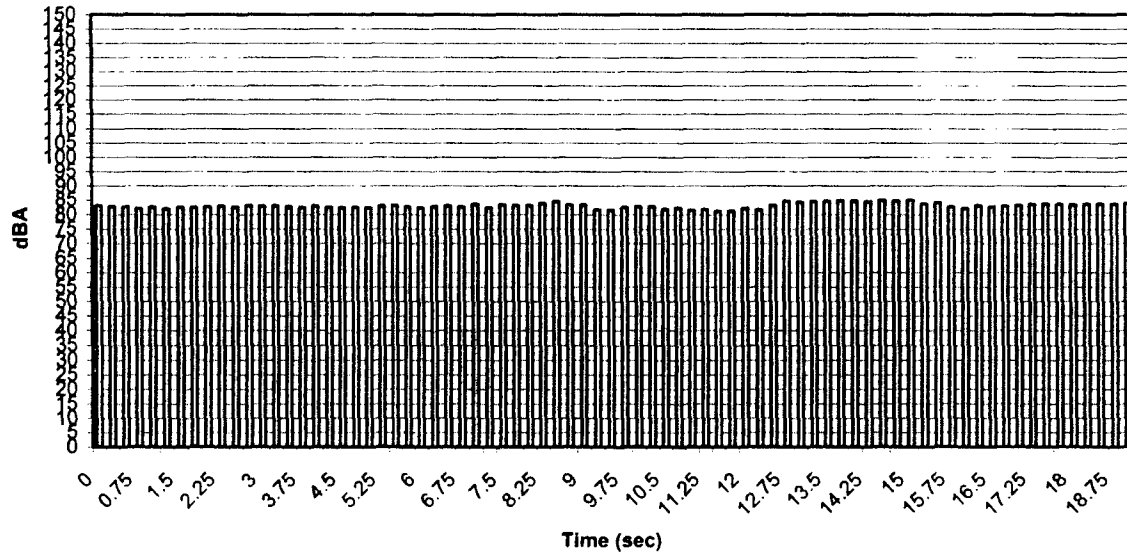


Figure A-8. Internal and External A-Weighted Time Histories for Condition 8.

E-3C 1981,Below Deck - Cruise  
Internal



E-3C 1981,Below Deck - Cruise  
External

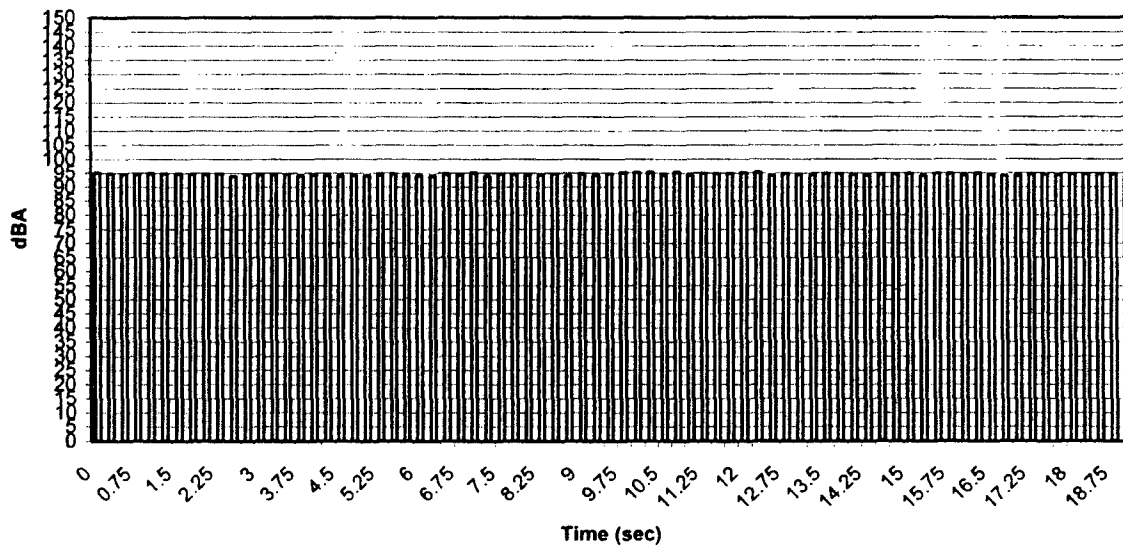
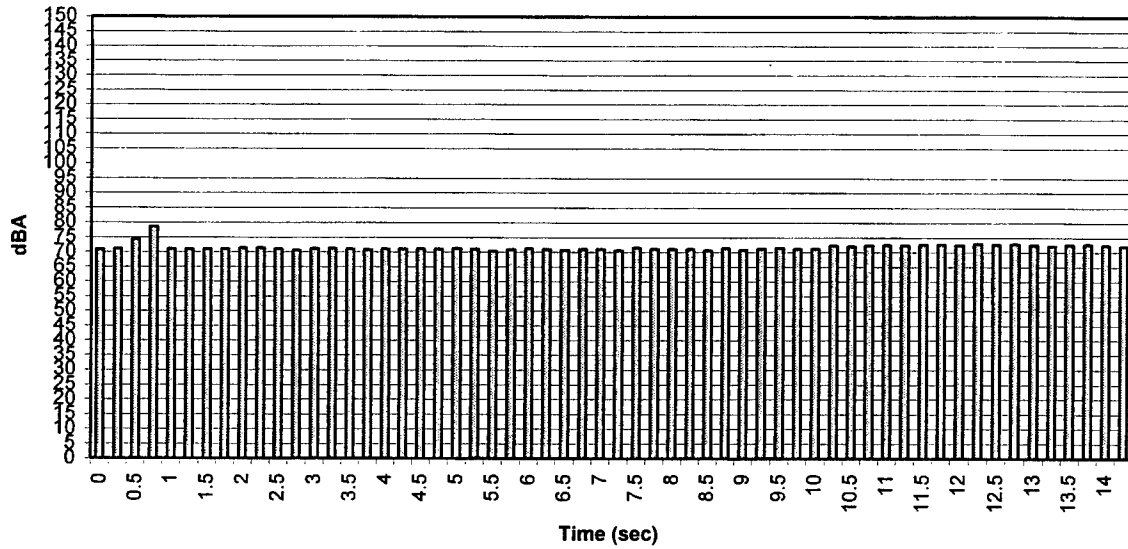


Figure A-9. Internal and External A-Weighted Time Histories for Condition 9.

E-3C 1981, Bed bunks (back bay) - Cruise  
Internal



E-3C 1981, Bed bunks (back bay) - Cruise  
External

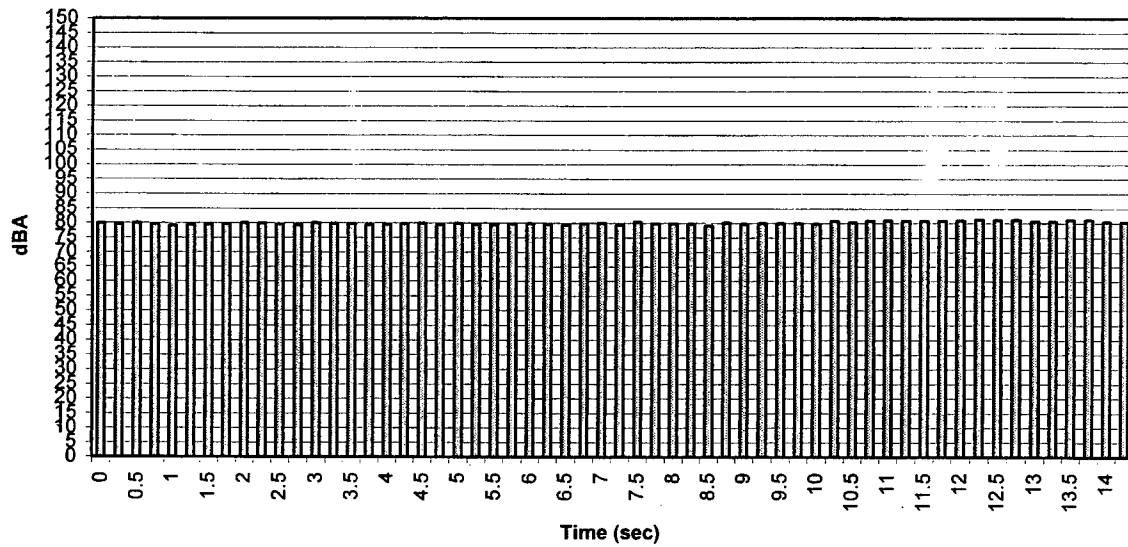
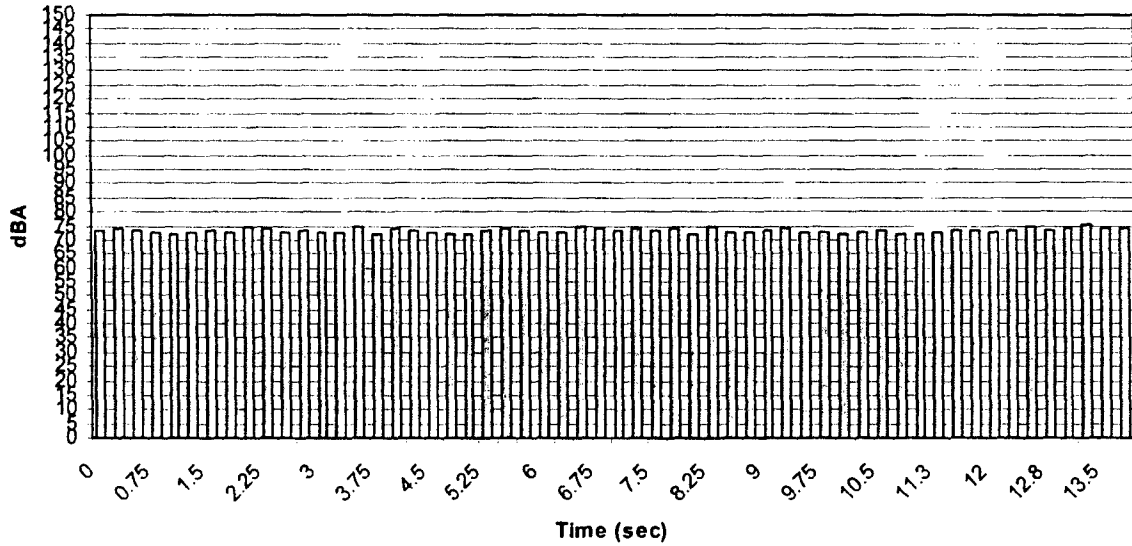


Figure A-10. Internal and External A-Weighted Time Histories for Condition 10.

E-3C 1981,RJ-Climb-Back Bay- ANR On  
Internal



E-3C 1981,RJ-Climb-Back Bay- ANR Off  
Internal

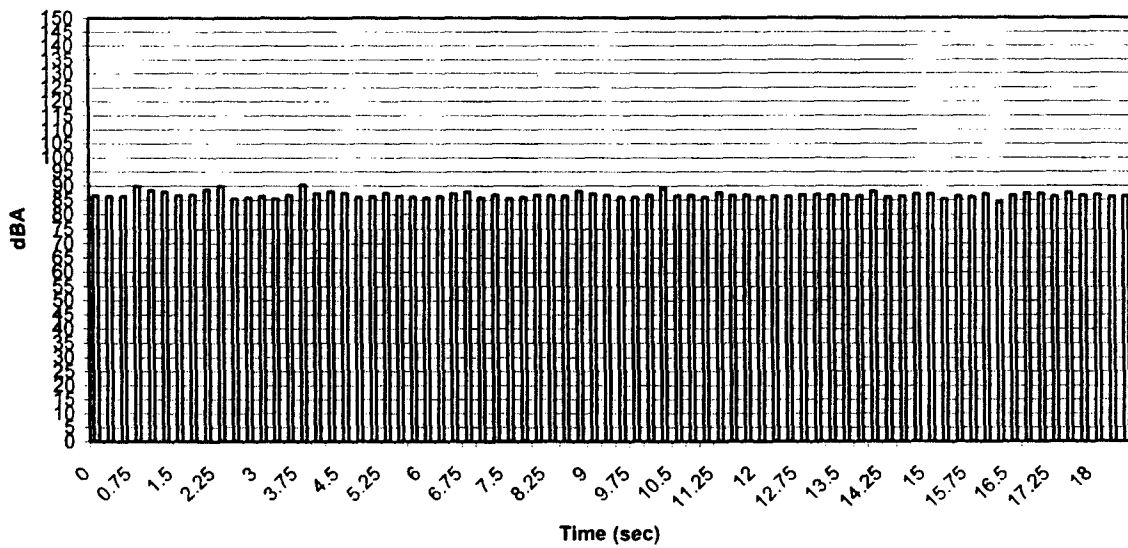


Figure A- 11. A-Weighted Time History for Condition 11, Internal ANR On and Off Spectra.

E-3C 1981,RJ-Climb-Back Bay- ANR Off  
External

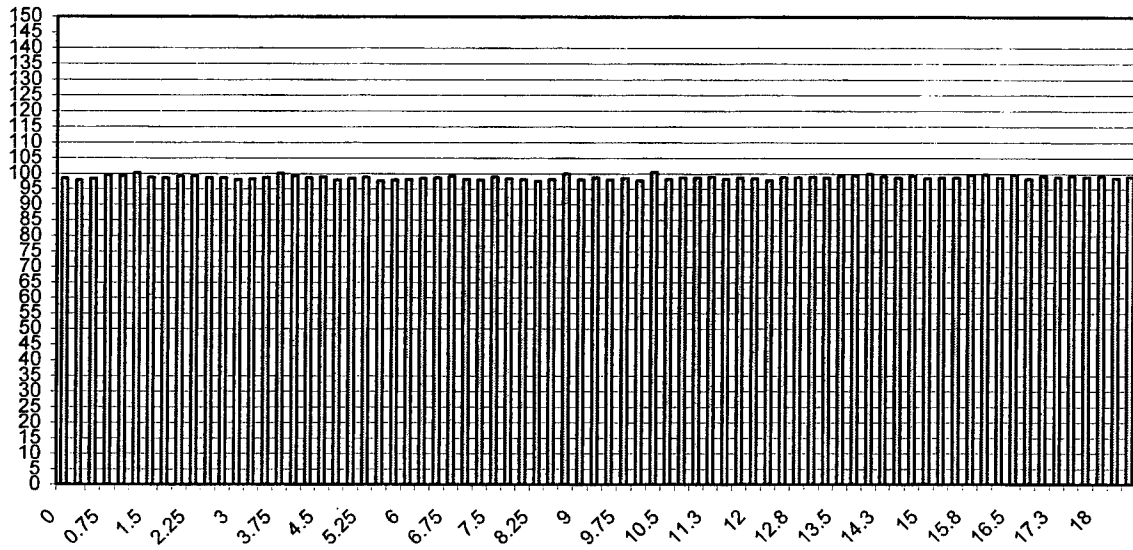
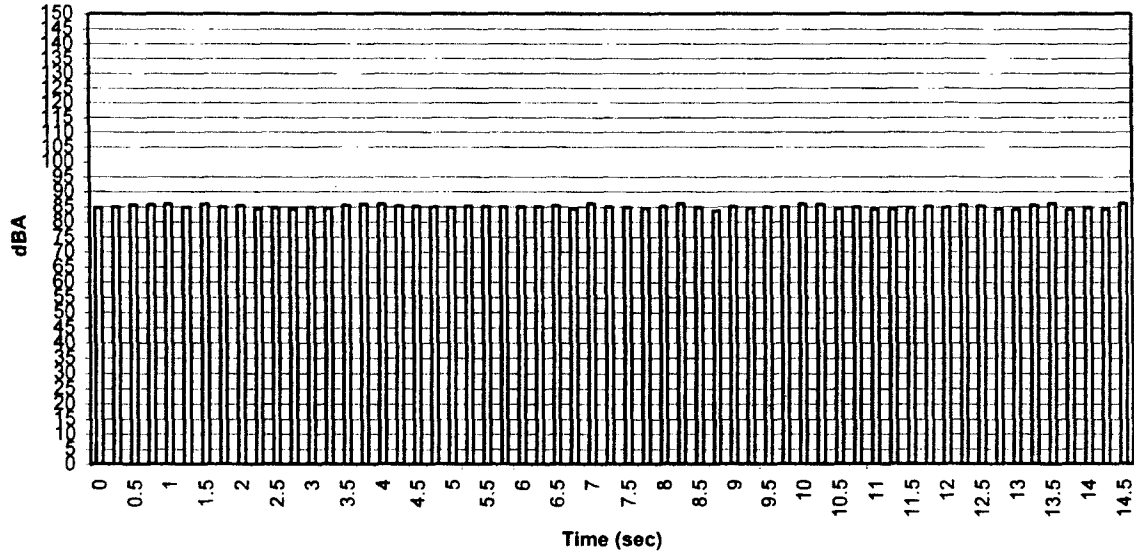


Figure A- 12. A-Weighted Time History for Condition 11, External Spectra.

E-3C 1981,RJ-Cruise-Back Bay- ANR Off  
Internal



E-3C 1981,RJ-Cruise-Back Bay- ANR On  
Internal

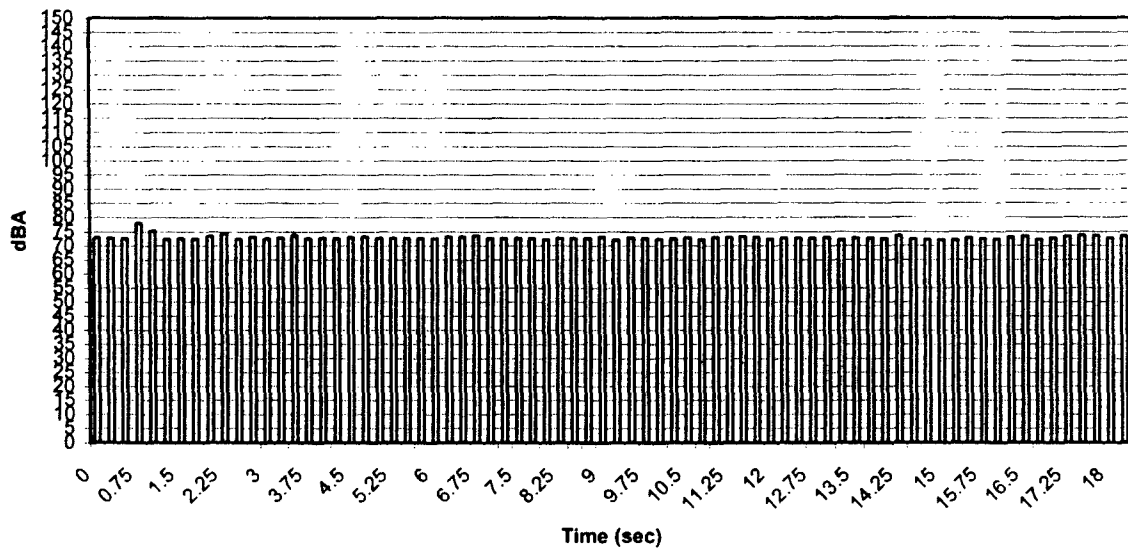


Figure A- 13. A-Weighted Time History for Condition 12, Internal ANR On and Off Spectra



E-3C 1981,RJ-Cruise-Back Bay- ANR On  
External

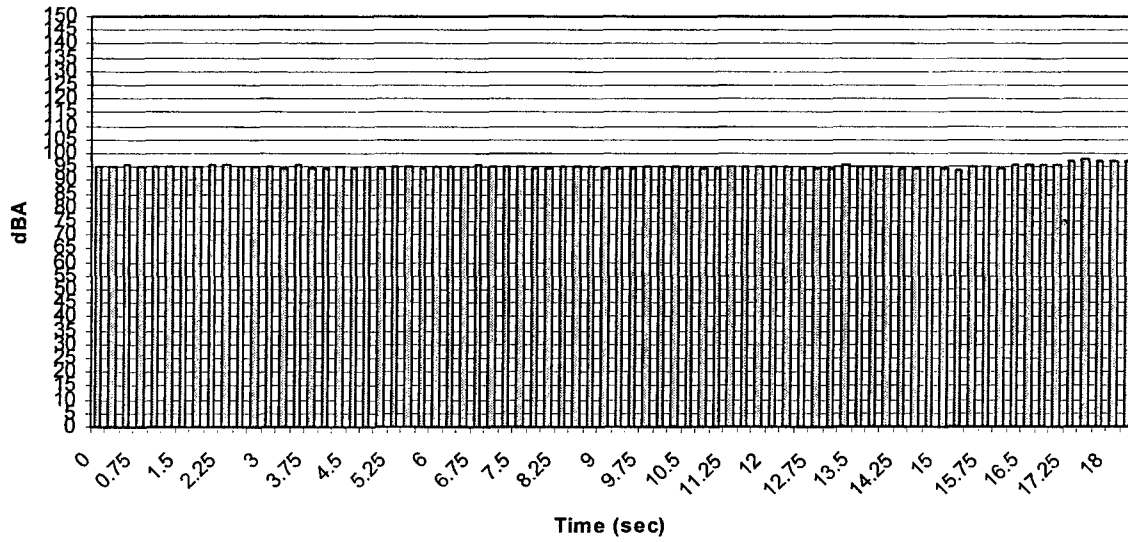
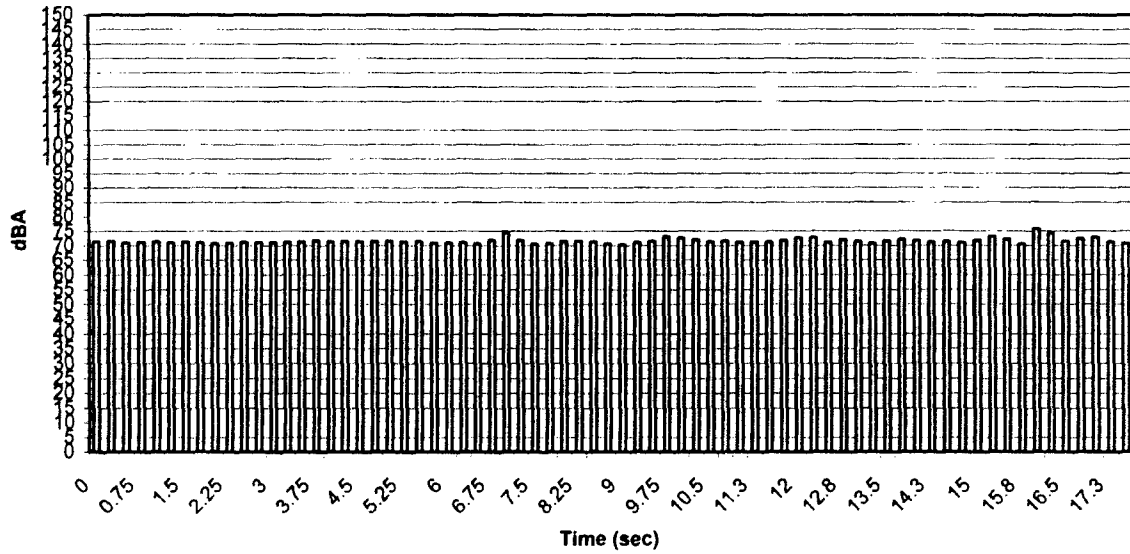


Figure A- 14. A-Weighted Time History for Condition 12, External Spectra.

E-3C 1981,RJ-Cruise-Seat 25- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 25- ANR Off  
Internal

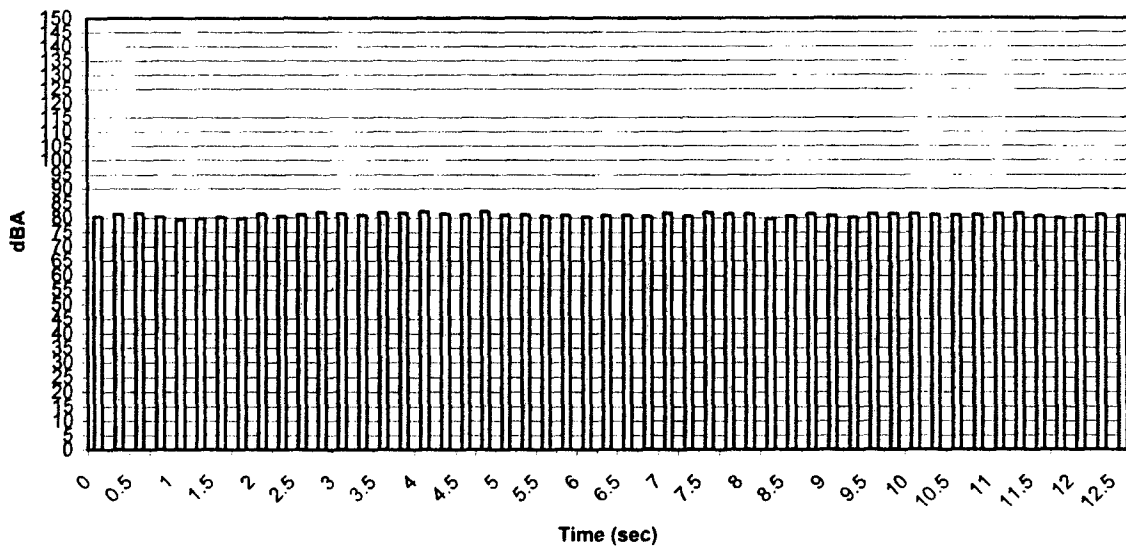


Figure A- 15. A-Weighted Time History for Condition 13, Internal ANR On and Off Spectra.

E-3C 1981,RJ-Cruise-Seat 25- ANR Off  
External

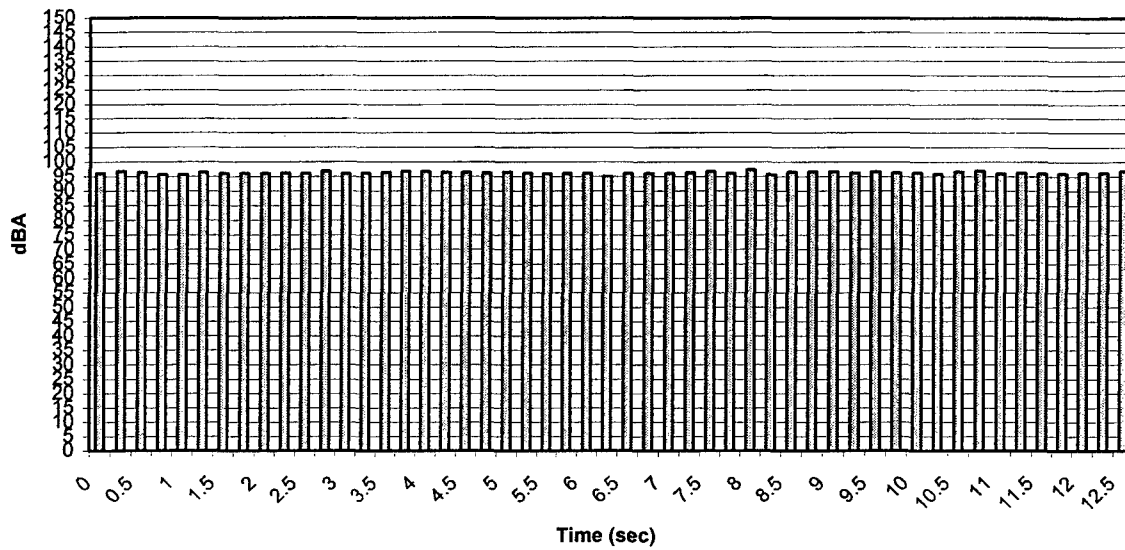
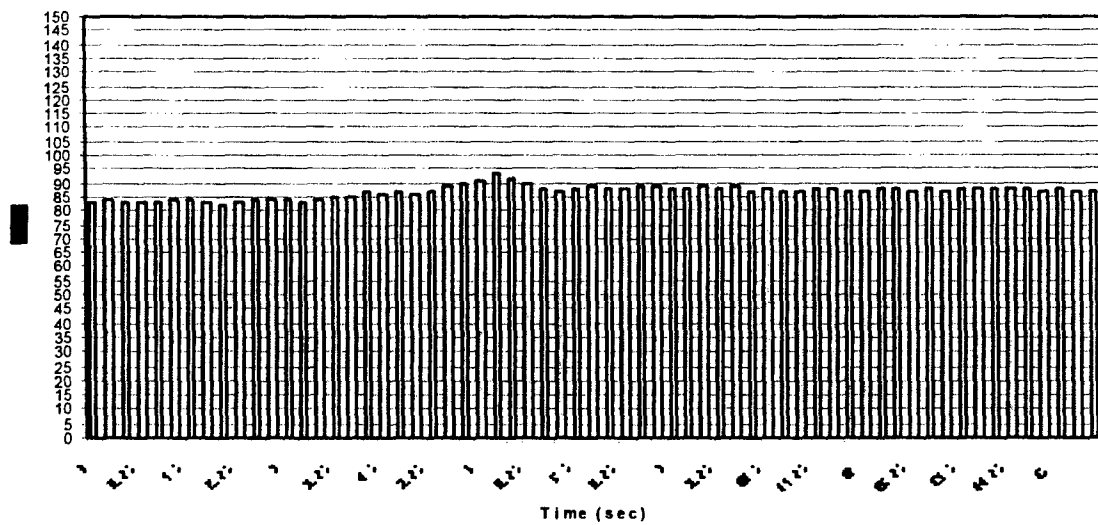


Figure A- 16. A-Weighted Time History for Condition 13, External Spectra.

E-3C 1981,RJ-Cruise-BelowDeck- ANR Off  
Internal



E-3C 1981,RJ-Cruise-BelowDeck- ANR Off  
External

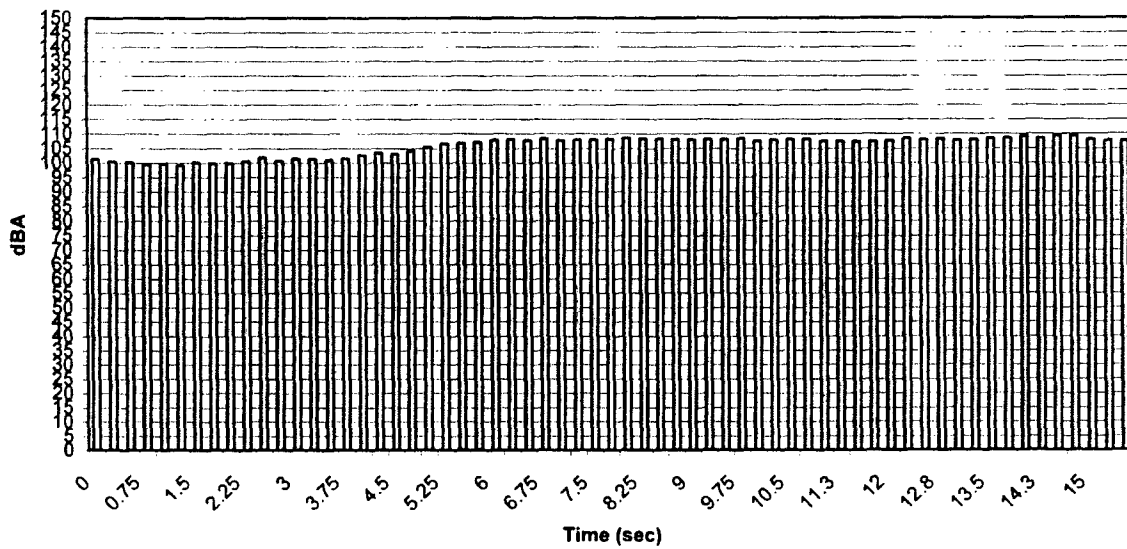
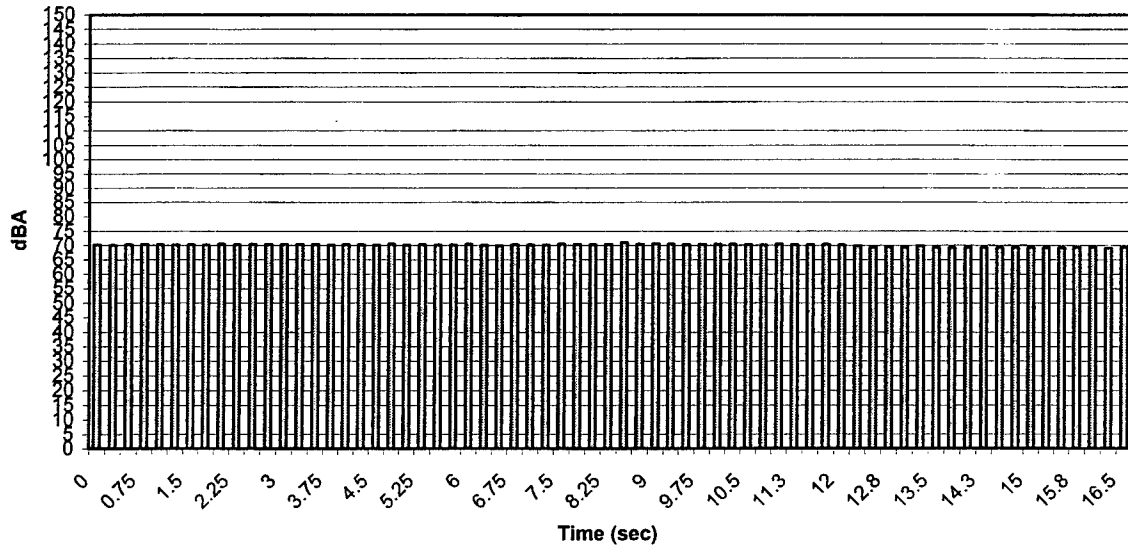


Figure A- 17. A-Weighted Time History for Condition 14, Internal and External Spectra.

E-3C 1981,RJ-Cruise-Seat 11- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 11- ANR Off  
Internal

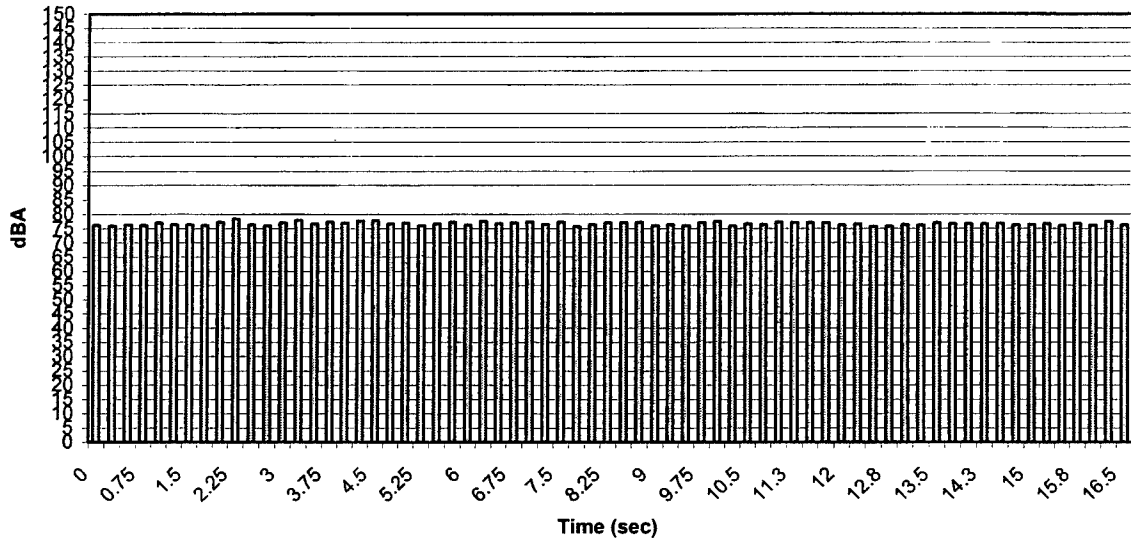


Figure A- 18. A-Weighted Time History for Condition 15, Internal ANR On and Off Spectra

E-3C 1981,RJ-Cruise-Seat 11- ANR O  
External

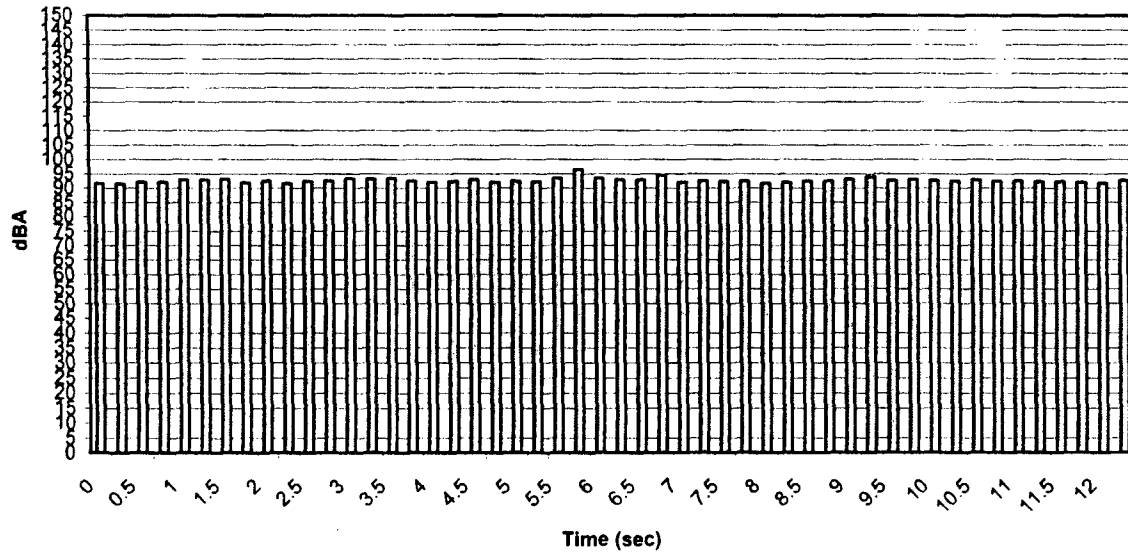
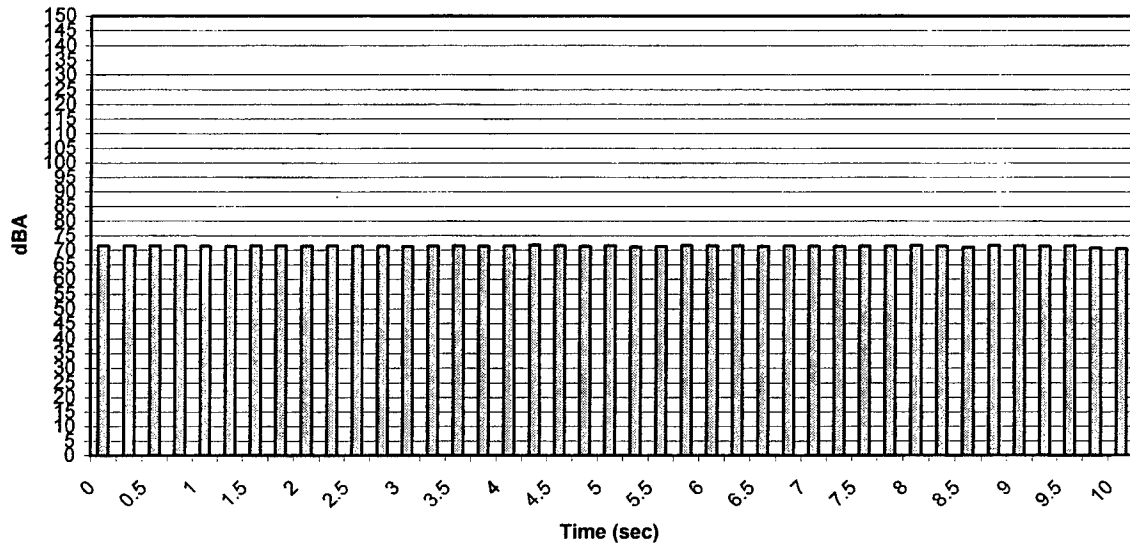


Figure A- 19. A-Weighted Time History for Condition 15, External Spectra.

E-3C 1981,RJ-Cruise-Seat 7- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 7- ANR Off  
Internal

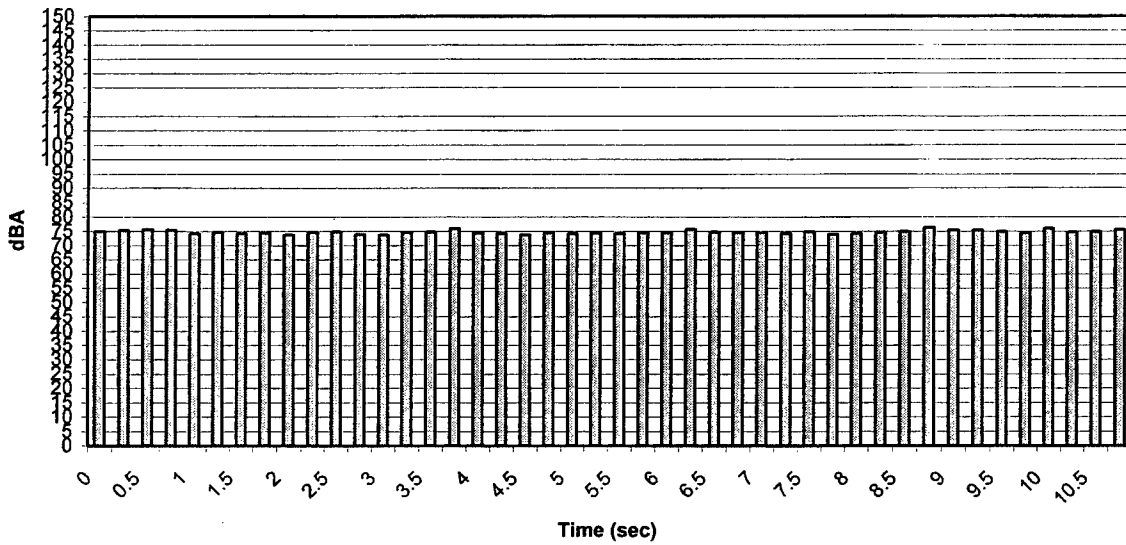


Figure A- 20. A-Weighted Time History for Condition 16, Internal ANR On and Off Spectra

E-3C 1981,RJ-Cruise-Seat 7- ANR On  
External

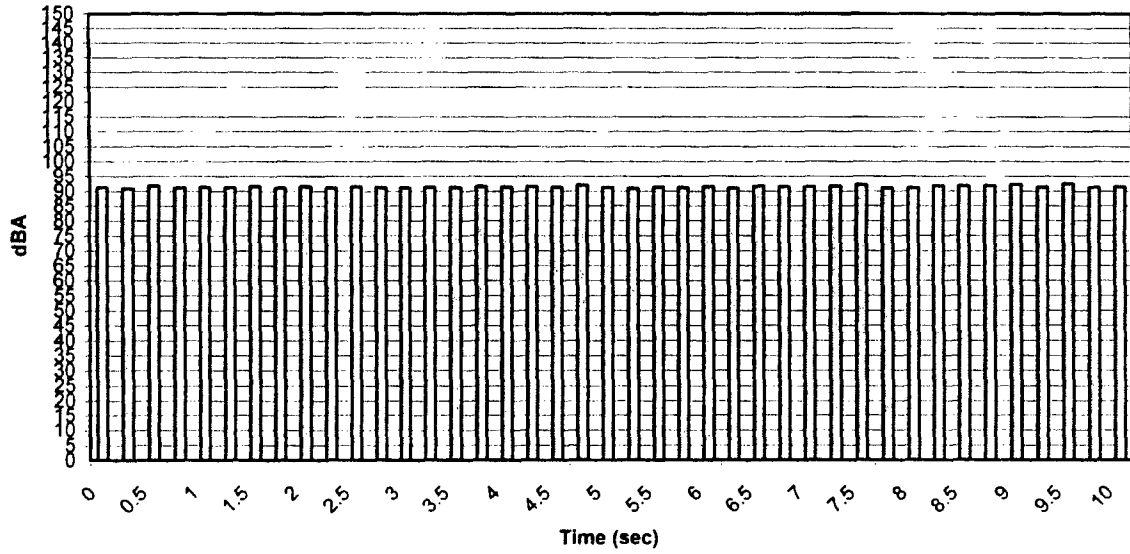
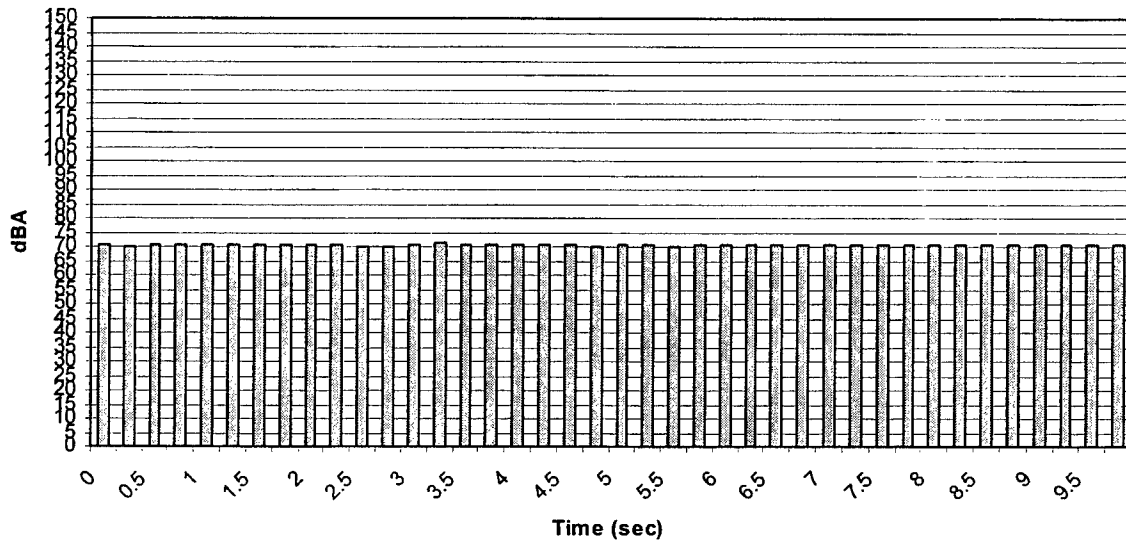


Figure A- 21. A-Weighted Time History for Condition 16, External Spectra.



E-3C 1981,RJ-Cruise-Seat 24- ANR On  
Internal



E-3C 1981,RJ-Cruise-Seat 24- ANR Off  
Internal

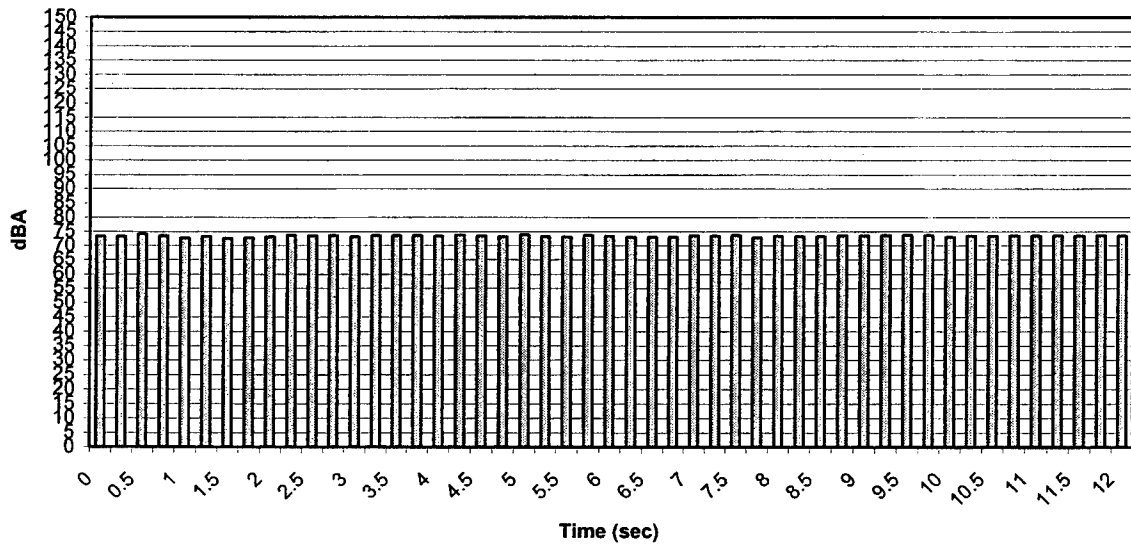


Figure A- 22. A-Weighted Time History for Condition 17, Internal ANR On and Off Spectra

E-3C 1981,RJ-Cruise-Seat 24- ANR Off  
External

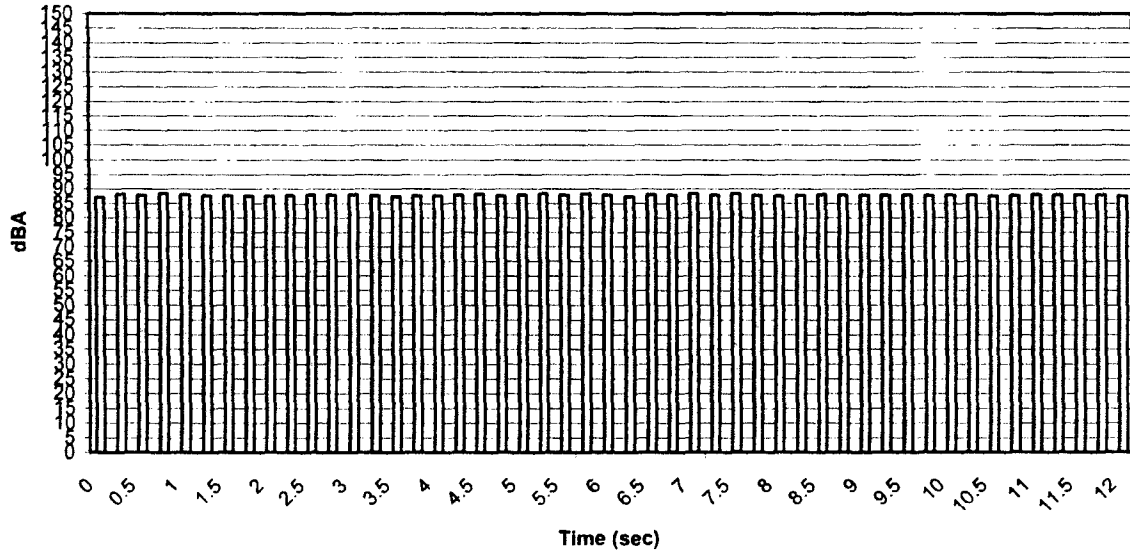


Figure A- 23. A-Weighted Time History for Condition 17, External Spectra.

## Appendix B – Procedure for Calculation of Time for Total Daily Exposure

Equations and Methods for Calculating Maximum Time of Exposure due to a noise level. These calculations are based on the Air Force regulation that sets the limits at 85 dB for 8 hours.

$$\text{ref}_{\text{level}} := 85 \quad \text{MT} := 8\text{hr} \quad \text{TDE} := 1$$

The Total Daily Exposure is calculated from the following formula:

$$\text{TDE} = \sum_{i=1}^n \frac{t_i}{8} \cdot 2^{\frac{L_i - 85}{3}}$$

This is a sum of all levels that a person is exposed to. These calculations then should be understood to give the exposure for a person in a single noise environment that does not vary more than 3 dB over the time that the individual is in the environment. If the noise level does exceed this 3 dB limit the time is cut in half. To calculate the time for a single level we remove the summation and invert the equation.

$$\text{TDE} = \frac{t}{\text{MT}} \cdot 2^{\frac{L - \text{ref}_{\text{level}}}{3}} \quad \text{TDE} \cdot \text{MT} = t \cdot 2^{\frac{L - \text{ref}_{\text{level}}}{3}}$$

$$\text{TDE} \cdot \text{MT} \cdot 2^{-\frac{L - \text{ref}_{\text{level}}}{3}} = t$$

Now we will give a few examples:

$$t(L) := \text{TDE} \cdot \text{MT} \cdot 2^{-\frac{L - \text{ref}_{\text{level}}}{3}}$$

$$t(125) = 3 \text{ s}$$

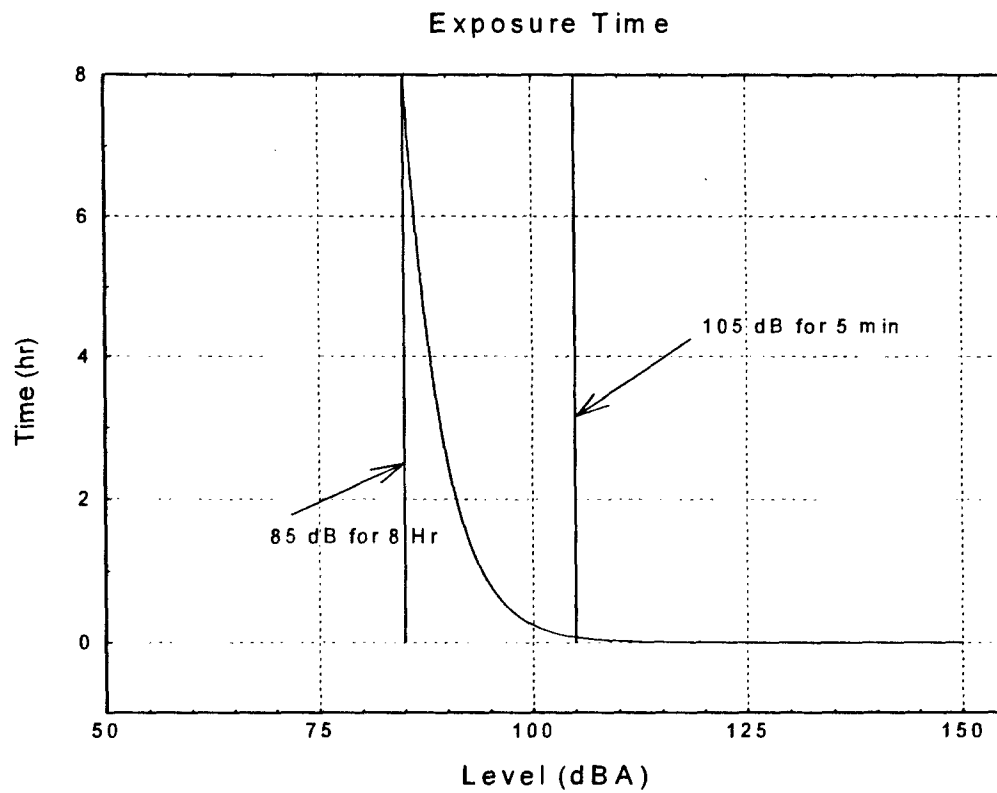
$$t(115) = 28 \text{ s}$$

$$t(105) = 5 \text{ min}$$

$$t(95) = 48 \text{ min}$$

$$t(85) = 8 \text{ hr}$$

$$t(75) = 81 \text{ hr}$$



**Figure B-1. Time of Allowable Exposure as a Function of Level**

## Appendix C – Calculation of Exposure In Each Ear Due to Net 4 Condition



Figure C-1. The Net4 Condition.

It was determined that the majority of the E-3 crewmembers will wear the headsets in a condition called 'Net 4'. This is a configuration where one ear cup is worn off the ear. This is to afford easier communication with other crewmembers. This will cause a different exposure for each ear. The ear that is exposed to the ambient level will have a lower exposure time and a higher exposure. Table C-1 shows the calculations based on the 10 conditions using the ambient levels to compute the exposure for the right ear (the unprotected ear) and the left ear (the protected ear) for the current headset, the David Clark 1076. Table C-2 shows the 7 conditions for the David Clark 1076-XL headset.

Table C-1. Calculations for the Maximum Time an Aircrew Member Can Spend in Net4.

Condition	Left Ear		Right Ear	
	Avg. Level	Max Time (hr)	Avg. Level	Max Time (hr)
Observer Seat 5 - Taxi	74.9	81.8	81.9	16.5
Observer Seat 5 - Takeoff	69.6	283.8	83.3	11.8
Observer Seat 5 - Climb	69.7	271.7	82.1	15.6
Observer Seat 5 - Cruise	68.2	384.7	80.3	23.4
Seat 25 - Cruise	69.2	311.2	78.6	34.8
Seat 11 - Cruise	77.1	49.2	84.9	8.2
Seat 7 - Cruise	75.3	74.9	78.4	36.8
Seat 14 - Cruise	74.8	84.7	78.1	39.2
Below Deck - Cruise	83.2	12.1	94.7	0.9
Bed bunks (back bay) - Cruise	71.9	165.2	80.1	24.9

**Table C-2. Calculations for the Maximum Time an Aircrew Member Can Spend in Net4.**

Condition	Left Ear		Right Ear	
	Avg. Level	Max Time (hr)	Avg. Level	Max Time (hr)
Climb-Back Bay- ANR Off	87.0	5.0	98.9	0.3
Climb-Back Bay- ANR On	73.4	118.0	98.9	0.3
Cruise-Back Bay- ANR Off	85.2	7.6	95.3	0.7
Cruise-Back Bay- ANR On	73.1	125.3	95.3	0.7
Cruise-Seat 25- ANR Off	81.1	19.8	96.4	0.6
Cruise-Seat 25- ANR On	71.7	171.6	96.4	0.6
Cruise-Below Deck- ANR Off	87.3	4.7	106.9	0.1
Cruise-Seat 11- ANR Off	76.7	54.0	92.9	1.3
Cruise-Seat 11- ANR On	70.1	250.6	92.9	1.3
Cruise-Seat 7- ANR Off	74.8	83.8	91.6	1.7
Cruise-Seat 7- ANR On	71.5	179.7	91.6	1.7
Cruise-Seat 24- ANR Off	73.5	114.3	88.0	4.0
Cruise-Seat 24- ANR On	70.7	219.1	88.0	4.0

## Appendix D – Approximation of Ground Crew Levels Using Headset Attenuation Data

AFRL/HECB has characterized the attenuation of the David Clark 1076-XL headset. Using this data, the attenuated noise levels that a person is exposed to may be approximated. To appropriately calculate the new A-weighted values, use Equation D-1.

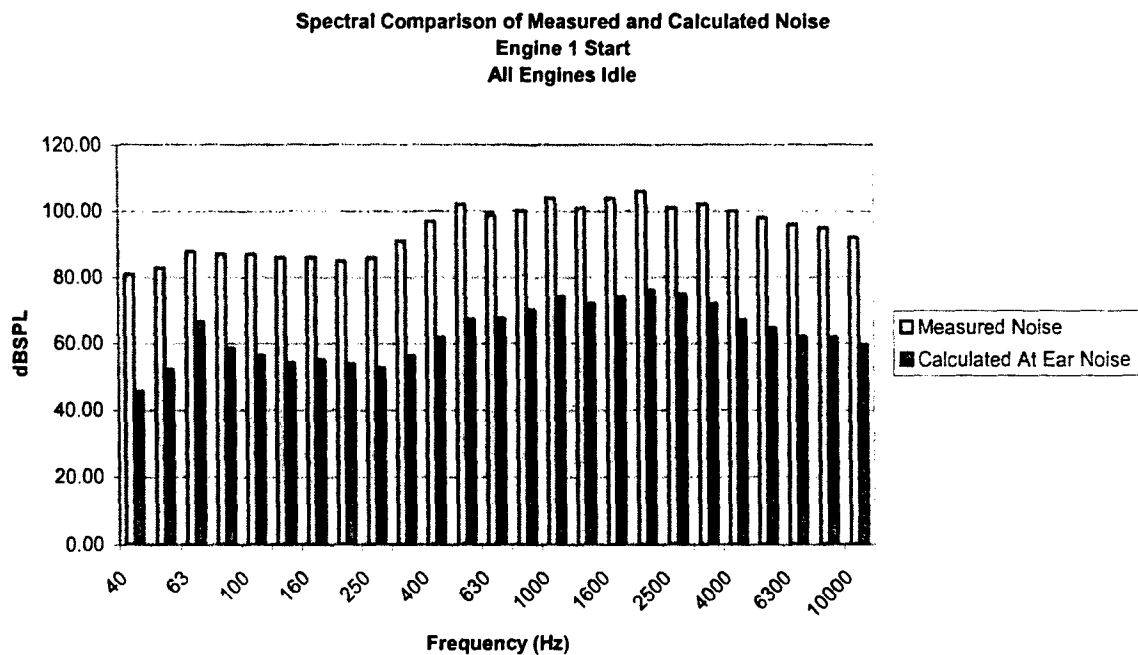
$$L_A = 10 \cdot \log_{10} \left[ \sum_{i=10}^{42} 10^{\frac{SPL_i - MIRE_i - A_{w_i}}{10}} \right]$$

Equation D-1. Equation to Calculate the A-weighted Level at the Ear.

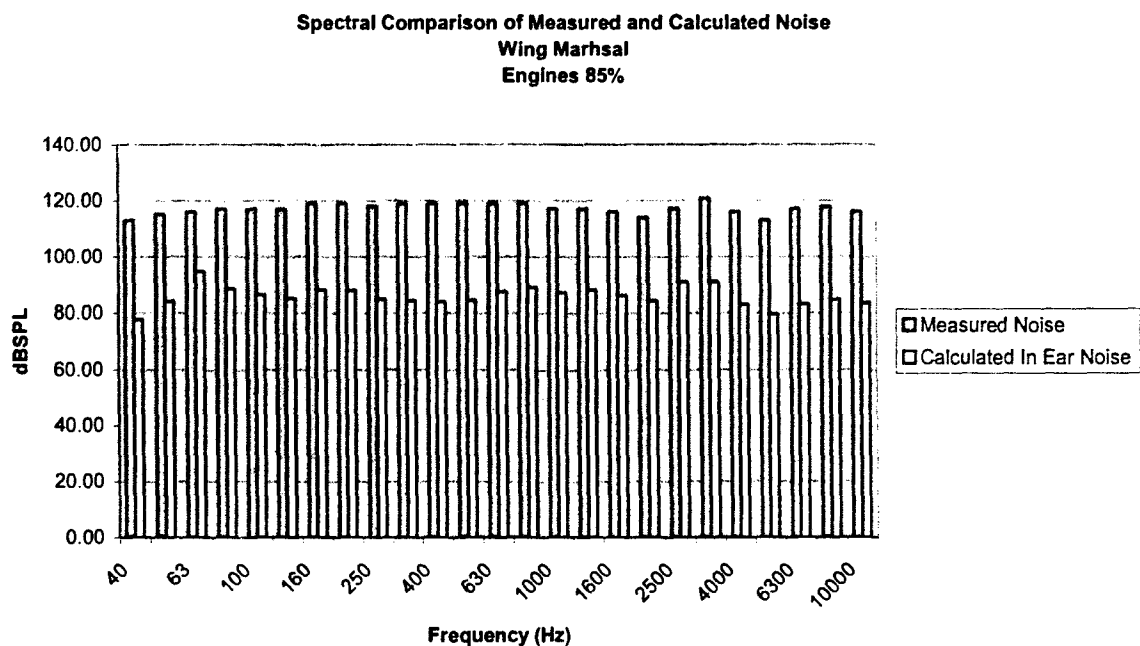
The calculated values are found in Table D-1 and two spectral representations follow.

Table D- 1. Measured and Calculated Levels for E-3A Ground Crew.

Position	Condition	Level (dBA)	
		Measured	Calculated
Engine #4 Start	Engine #4 Idle	111.00	80.68
Engine #3 Start	Engines #3 and 4 Idle	113.10	82.92
Engine #2 Start	Engines #2, 3, and 4 Idle	110.10	79.87
Engine #1 Start	All Engines Idle	113.30	82.75
Air Hose Removal	All Engines Idle	111.40	81.97
Electric Disconnect	All Engines Idle	109.80	79.64
Wheel Chock Pull	All Engines Idle	116.00	85.69
Wing Marshal	All Engines Idle	110.10	79.78
Wing Marshal	All Engines 85% RPM	129.30	98.29
Trim Adjustment	All Engines Idle	120.30	89.88



**Figure D-1. Spectral Comparison of the Noise Levels for E-3A Ground Crew, Engine 1 Start.**



**Figure D-2. Spectral Comparison of the Noise Levels for the E-3A Ground Crew, Wing Marshal, Engines 85%.**



## **Appendix E – References for Noise Measurement**

### **REFERENCES**

- AMRL/BBE-SP-7, "Standard Procedure For Performing 1/3 Octave Band Spectral Analysis of Time Varying and Stationary Signals Using the GR Analyzer."
- AMRL/BBE-SP-9, "Standard Procedure for Free-Field Comparison Micro-phone Comparison."
- AMRL/BBE-SP-11, "Standard Procedure for Calibration of B&K 4220 Piston Phones and B&K 4230 Field Calibrators."

### **REQUIREMENTS**

- Air Force Occupational Safety and Health Standard 48-19, Hazardous Noise Program
- Code of Federal Regulations, Title 29, Chapter XVII, Part 1910, Subpart G
- ANSI Std. S12.6-1997 (Real Ear Attenuation at Threshold Method for the Measurement of Attenuation of Hearing Protection Devices)
- ANSI Std. S12.42-1995 (Microphone in Real Ear Method for the Measurement of Attenuation of Hearing Protection Devices)